NASA TECHNICAL
MEMORANDUM

Report No. 53833

MARSHALL SPACE FLIGHT CENTER GRAVITY NETWORK

By William M. Greene
Space Sciences Laboratory

April 15, 1969

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

MSFC - Form 3190 (September 1968)

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA TM X-53833	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE MARSHALL SPACE FLIGHT CENTER GRAVITY NETWORK		5. REPORT DATE April 15, 1969
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) William M. Greene		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS Space Sciences Laboratory, S&E George C. Marshall Space Flight Center Marshall Space Flight Center, Ala. 35812		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
		14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

ABSTRACT

Initial field seismic measurements at proposed measurement sites for the Laser Absolute Gravimeter (LAG) were made at seven locations in and around Redstone Arsenal, Huntsville, Alabama. To meet the LAG test requirements, a local and statewide gravity net was established by the author. All data conclusively indicated the necessity for seismic isolation. This was achieved through utilization of numbers of techniques and the acquisition of an optimum, permanent field site.

17. KEY WORDS	18. DISTRIBUTION STATEMENT See Document Release Form		
19. SECURITY CLASSIF. (of this report) Uncl.	20. SECURITY CLASSIF. (of this page) Uncl.	21. NO. OF PAGES 58	22. PRICE

MSFC - Form 3292 (May 1969)

ACKNOWLEDGMENTS

The author would like to acknowledge the excellent support provided the gravimeter effort by Space Sciences Laboratory, Test Laboratory, Astrionics Laboratory, P&VE Laboratory, Aero-Astrodynamics Laboratory, and Quality Laboratory during the course of this initial phase of work.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Concluded)

LIST OF TABLES

TECHNICAL MEMORANDUM X-53833

MARSHALL SPACE FLIGHT CENTER GRAVITY NETWORK

SUMMARY

This report presents the results of field work accomplished in preparation for field testing of the Laser Absolute Gravimeter (LAG).

A local and statewide gravity net was established by the author to test the LAG.

Several methods for handling special associated equipment as well as the gravimeter were derived as a result of the work, and a number of noise damping techniques for use on actual measurement runs were also learned.

It was determined that the site at Green Acres had the least seismic interference of all sites tested. Therefore, this site was obtained as a permanent field base for the absolute gravimeter.

INTRODUCTION

This report presents the initial results of field work accomplished in preparation for field testing of the LAG which is currently being sponsored by NASA Headquarters, OSSA, Planetology and is under contract to SPACO, Huntsville, Alabama.

Gravity, as a natural phenomenon, was initially "discovered" when it was noticed that pendulum clocks varied in accuracy when moved from one latitude to another. It was determined from this discovery that the radius of the earth was not spherical but spheroid. Further scientific refinements showed that gravimetric measurements provided knowledge of the thickness of the earth's crust, as well as data pertinent to the shape of the earth.

Through the centuries, many methods for determining gravity were devised, all of which were inadequate for the computation of physical, geophysical, and astronomical quantities requiring an accurate, and absolute value for acceleration due to gravity.

In absolute measurements made at Potsdam from 1894 to 1904, a series of values were derived and designated as the "standard" to be used throughout the world. Subsequent measurements have given rise to strong disagreement regarding the precision of the "standard."

Several absolute gravimeter studies are in various stages of research and development throughout the world (Table I). However, none, except the MSFC Laser Absolute Gravimeter, is designed to make absolute measurements on the lunar surface.

Laser Absolute Gravimeter Development

A Michelson Interferometer is the basis for the laboratory model LAG being developed by Dr. O. K. Hudson and Mr. William Greene, of the Space Sciences Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama. This instrument is expected to produce accuracies not attained prior to its development. Several features are being engineered into the device making it uniquely attractive for extraterrestrial application in either manned or unmanned missions.

This LAG is an accelerometer especially designed to measure absolute gravity on the lunar surface. The machine will be "attache case" size, thereby providing convenient portability to an astronaut who will carry it during extraterrestrial surface exploration.

Development is to be accomplished in three major phases. Phase I consists of the design, construction, and testing of a working laboratory model. Phase II consists of the design, construction, and testing of a prototype flight model. Phase III consists of the design, construction, and testing of the flight model.

A working laboratory model has been constructed and is currently undergoing final stages of optimization (Fig. 1). It is anticipated that accuracies of one part in 10^{-7} will be realized upon completion of the present optimization effort.

TABLE I. ABSOLUTE GRAVIMETER STUDIES NOW IN PROGRESS

1.	Baglietto Institute of Geodesy University of Buenos Aires, Engineering Faculty Argentina
2.	Cook National Physics Laboratory of England Teddington, Middlesex, England
3.	Faller Air Force Cambridge Wesleyan University Middleton, Connecticut
4.	Hudson (Extraterrestrial and Terrestrial)[a] NASA, MSFC Marshall Space Flight Center, Alabama
5.	Kukkamaki Finnish Geodetic Institute Helsinki, Finland
6.	Rose Hawaii Institute of Geophysics University of Hawaii Hawaii
7.	Robertson Research Institute for Geodetic Science Alexandria, Virginia
8.	Sakuma French Bureau of Weights and Measures Paris, France
9.	The Military Geographical Institute Buenos Aires, Argentina

a. Not designed for measurements on the Earth

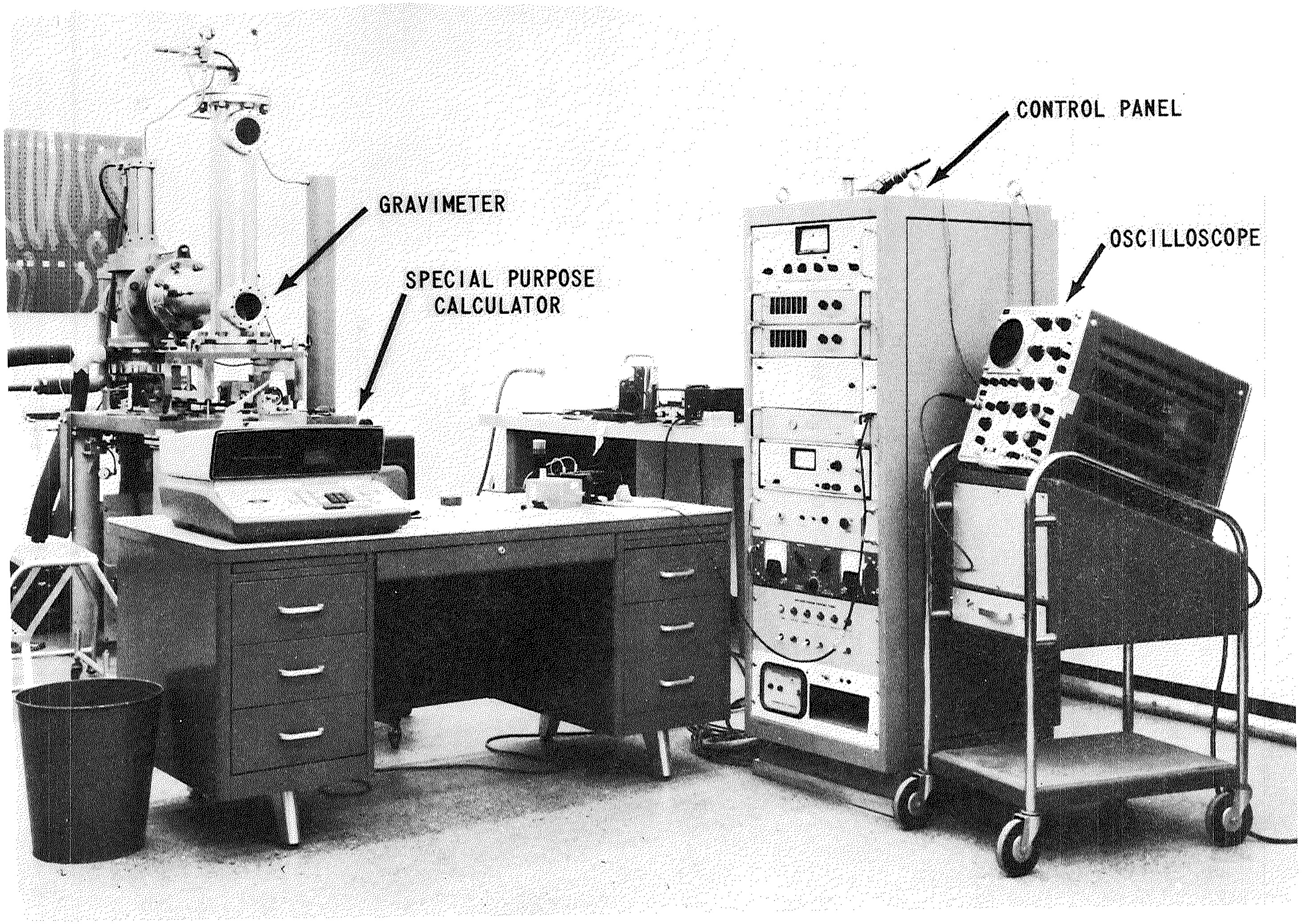


FIGURE 1. WORKING LABORATORY MODEL OF THE LASER ABSOLUTE GRAVIMETER

Gravimeter Operation

The gravimeter utilizes the principle of the Michelson Interferometer. A system of two mirrors and a beam splitter is used in conjunction with a gas laser (Fig. 2), the wavelength of which is 6329.9147 angstroms and whose long-term stability is 10^{-8}. One of the mirrors, M, is fixed (Fig. 2); the other is mounted in a free-falling body called "the bird" (Fig. 3). The determination of the acceleration due to gravity is dependent on measurement of position and time. An electronic counter determines the time by counting the number of oscillations of a standard oscillator, called "the clock." Another electronic counter determines distance by recording interference fringes (these fringes are the result of the combination of two beams of light having the same frequency, polarization, amplitude, and direction of propagation).

Resultant electrical data are fed through logic circuitry and translated into digital output which is displayed on a panel. This output is then fed manually into a computer which provides "g" readout.

FIELD TESTING

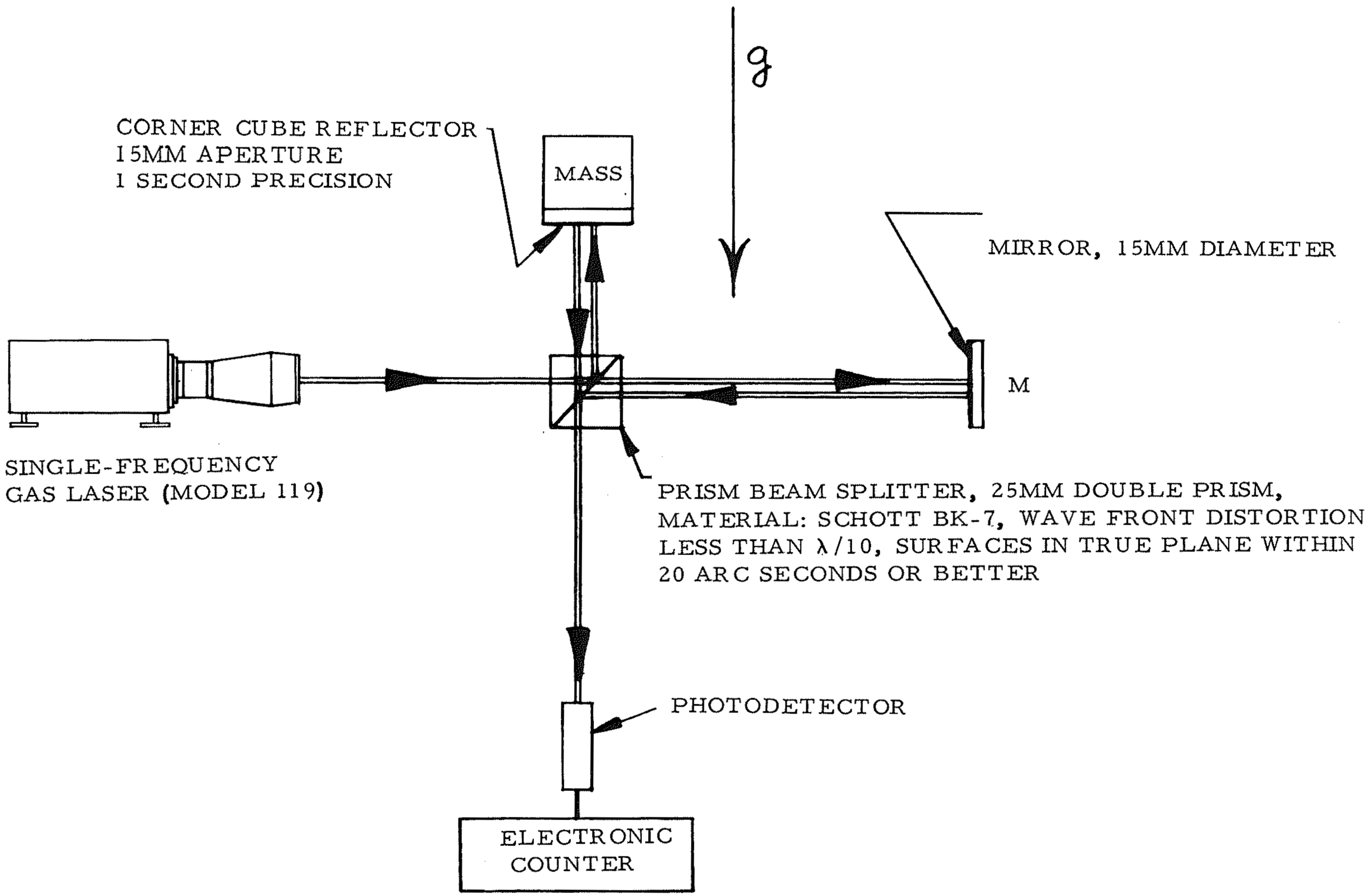
Upon completion of the laboratory model (Phase I) the gravimeter will be moved to the field and tested. A modified 1 1/2-ton truck will be used for moving the gravimeter. A special mechanical apparatus will facilitate moving the machine on and off the truck at various field sites.

The LAG must rest on the earth's surface in order to measure the absolute accelerations imparted to "the bird;" any accelerations of the earth's surface will add to or subtract from the observed gravitational accelerations and constitute an error in the desired absolute value of "g."

This report is concerned with initial field seismic measurements made at proposed gravity measurement sites for the following purposes:

(1) To gain as much familiarization as possible with seisms that may be expected at any of the "type" sites included here.

(2) To measure the efficiency of the noise-damping techniques, particularly air-table and lead-damping methods.



PRINCIPLE OF OPERATION
OF LASER GRAVIMETER

FIGURE 2. PRINCIPLE OF THE INTERFEROMETER

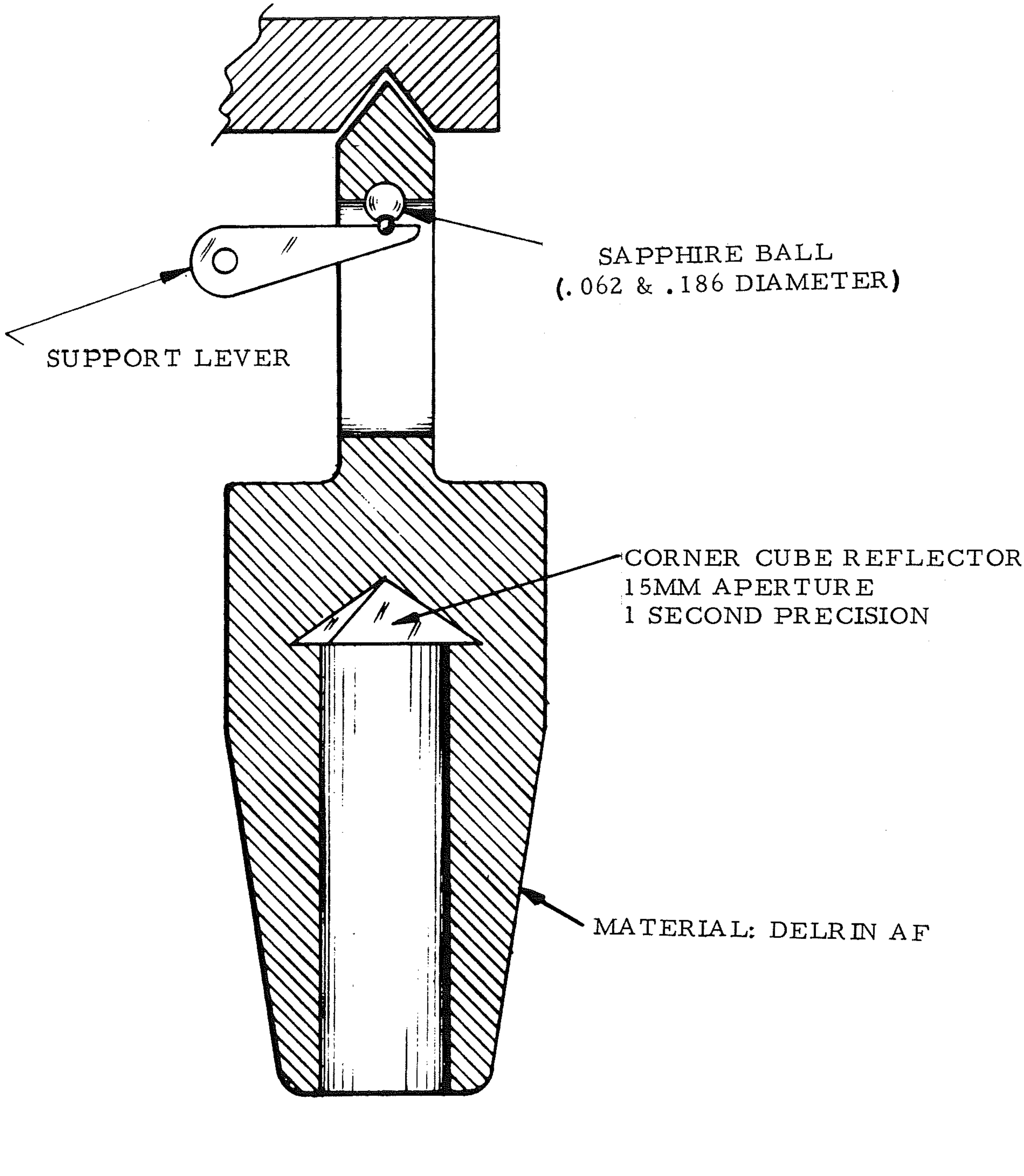


FIGURE 3. FREE-FALLING BODY — "THE BIRD"

(3) To accrue facts which will be instrumental in establishing techniques and procedures for handling data from the completed prototype field gravimeter.

(4) To establish guidelines through experience for equipment handling.

Testing requires a series of permanent stations and a "gravity net" having known relative values. These stations consist of an emplacement (e.g., a concrete slab) located at permanent installations such as an airport or public land area. Two of the largest existing, and available, established nets are the East Coast Gravity Net (Table II) extending from the Florida Keys to Maine (Fig. 4), and the North-South North American Gravity Net (Table III) extending from the equator to Alaska (Fig. 4). The differences in elevation along both these nets provide the necessary range of values to check the dynamic range of instrument performance.

Gravity Nets

Since adequate gravity nets did not exist, it became necessary to establish at least two nets locally to fulfill the initial requirements of the LAG. These comprise a new gravity net which the author has entitled the "Marshall Space Flight Center Gravity Net."

One of these, the "MSFC Huntsville Gravity Net" (Table IV), has its base at the permanent field station (Green Acres) on Redstone Arsenal (Fig. 5), elevation 585 feet; its second tie at Madkin Mountain (Fig. 6) on Redstone Arsenal, elevation 1235 feet; with an alternate site located on Green Mountain (Fig. 7), elevation 1365 feet; and its third tie on the TVA Reservation at Guntersville (Fig. 8), elevation 640 feet. Accessibility, permanency, and elevation differential were the major considerations in selection of this first net.

The second net, the MSFC Alabama Gravity Net (Table V), provides statewide coverage. Its base is at Green Acres in Huntsville, elevation 585 feet; its first tie at Birmingham, elevation 700 feet; and its second tie at Montgomery, elevation 150 feet.

TABLE II. EAST COAST GRAVITY NET

1.	Key West, Florida	19.	Ridgeland, South Carolina
2.	Homestead, Florida	20.	Greenpond, South Carolina
3.	Miami, Florida	21.	Charleston, South Carolina
4.	West Palm Beach, Florida	22.	Georgetown, South Carolina
5.	Stuart, Florida	23.	Wilmington, North Carolina
6.	Vero Beach, Florida	24.	Elizabeth, North Carolina
7.	Melbourne, Florida	25.	Norfolk, Virginia
8.	Cocoa Beach, Florida	26.	Richmond, Virginia
9.	Orlando, Florida	27.	Fredericksburg, Virginia
10.	Sanford, Florida	28.	Washington, D. C.
11.	Daytona Beach, Florida	29.	Baltimore, Maryland
12.	Bunnell, Florida	30.	Wilmington, Delaware
13.	St. Augustine, Florida	31.	Philadelphia, Pennsylvania
14.	Jacksonville, Florida	32.	Princeton, New Jersey
15.	Kingsland, Georgia	33.	New Haven, Connecticut
16.	Brunswick, Georgia	34.	Boston, Massachusetts
17.	Riceboro, Georgia	35.	Portland, Maine
18.	Savannah, Georgia	36.	Bangor, Maine

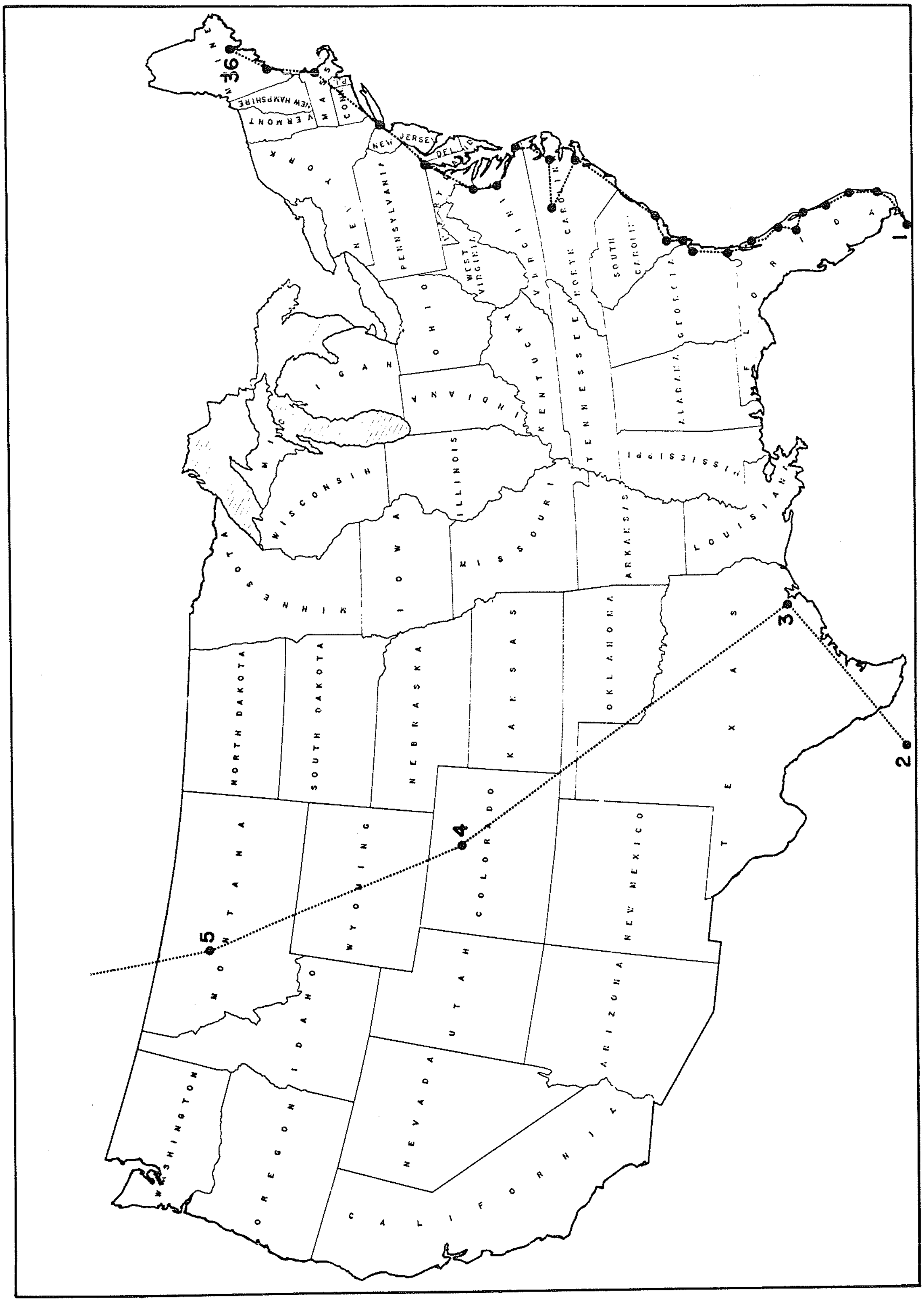


FIGURE 4. EAST COAST AND NORTH-SOUTH NORTH AMERICAN GRAVITY NET

TABLE III. NORTH-SOUTH NORTH AMERICAN GRAVITY NET

1.	Mexico City, Mexico
2.	Monterrey, Mexico
3.	Houston, Texas
4.	Boulder, Colorado
5.	Fort Scott, Montana
6.	Edmonton, British Columbia
7.	Whitehorse, Yukon Territory
8.	Point Barrow, Alaska

TABLE IV. MSFC (HUNTSVILLE) GRAVITY NET

Base: Green Acres
Location: 0.8 mile northwest of the intersection between Martin and Anderson Roads on Redstone Arsenal, Huntsville, Alabama. The site is on a concrete pad located in the middle of a field (Fig. 5).
Tie 1: Madkin Mountain
Location: 0.8 mile northeast of the intersection between Neal and Martin Roads on Redstone Arsenal, Huntsville, Alabama. The site is located on a 3-by-3-foot concrete pad about 50 feet west of the facility buildings (Fig. 6).
Tie 2: Tennessee Valley Authority Reservation
Location: 0.2 mile east of Federal Highway 241 and 0.5 mile due north of the north end of Guntersville Dam, Guntersville, Alabama (Fig. 7).

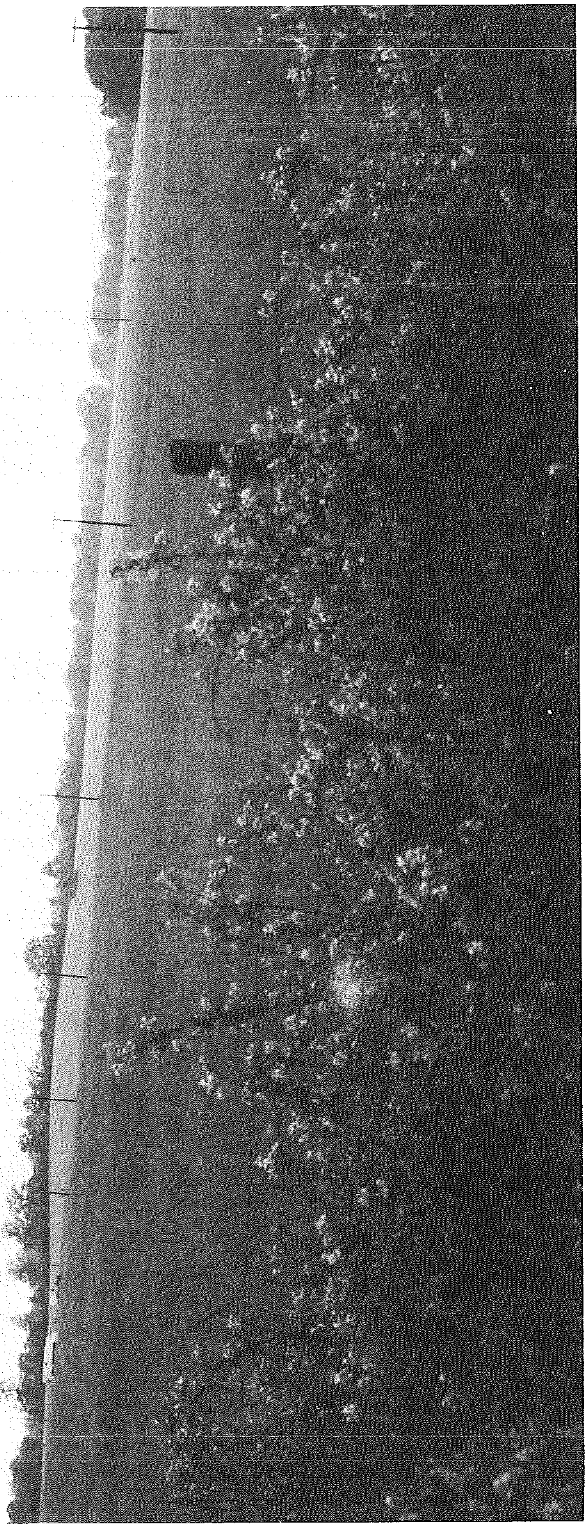


FIGURE 5. GREEN ACRES

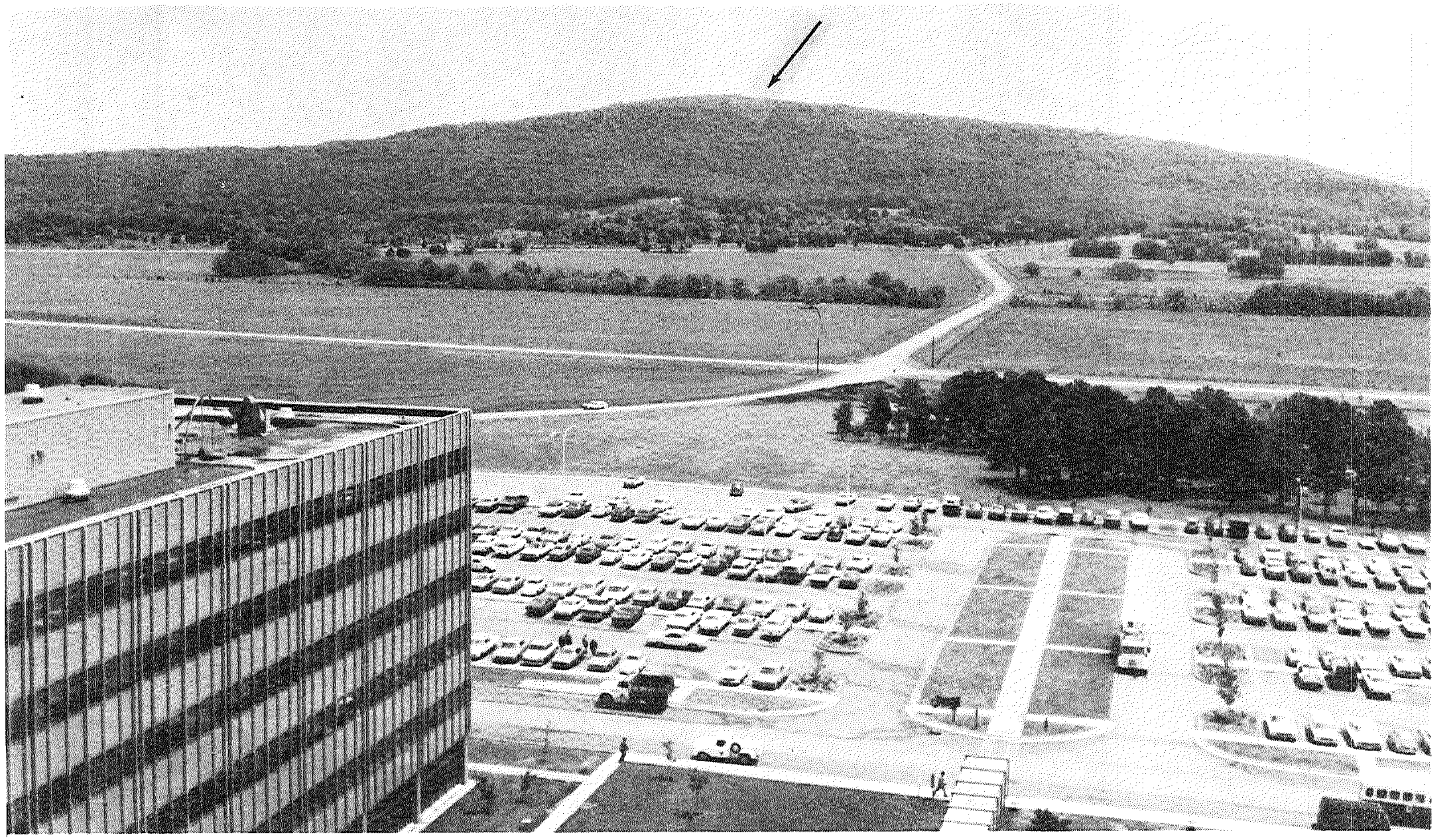


FIGURE 6. MADKIN MOUNTAIN

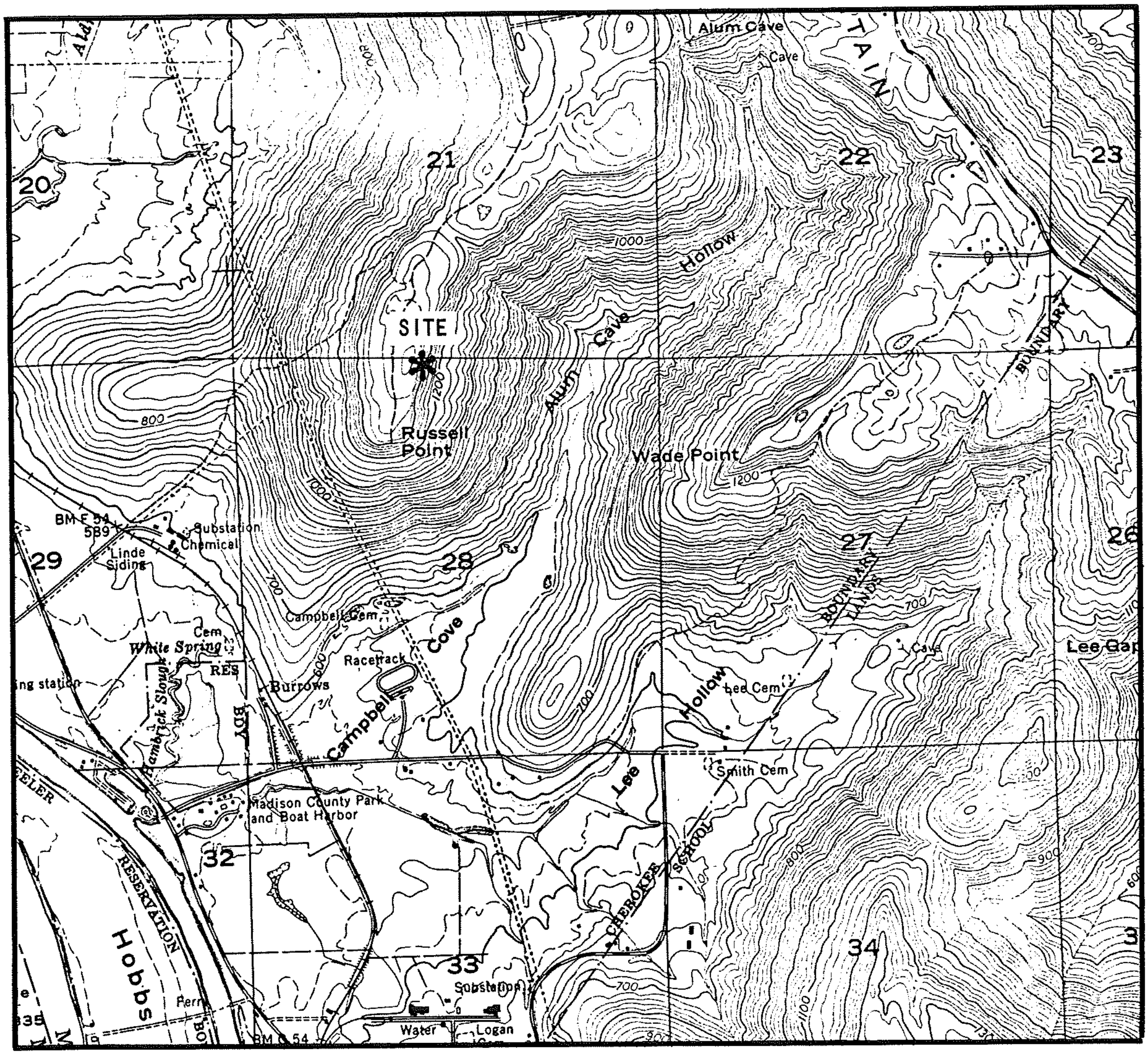


FIGURE 7. MAP LOCATION OF THE GREEN MOUNTAIN SITE

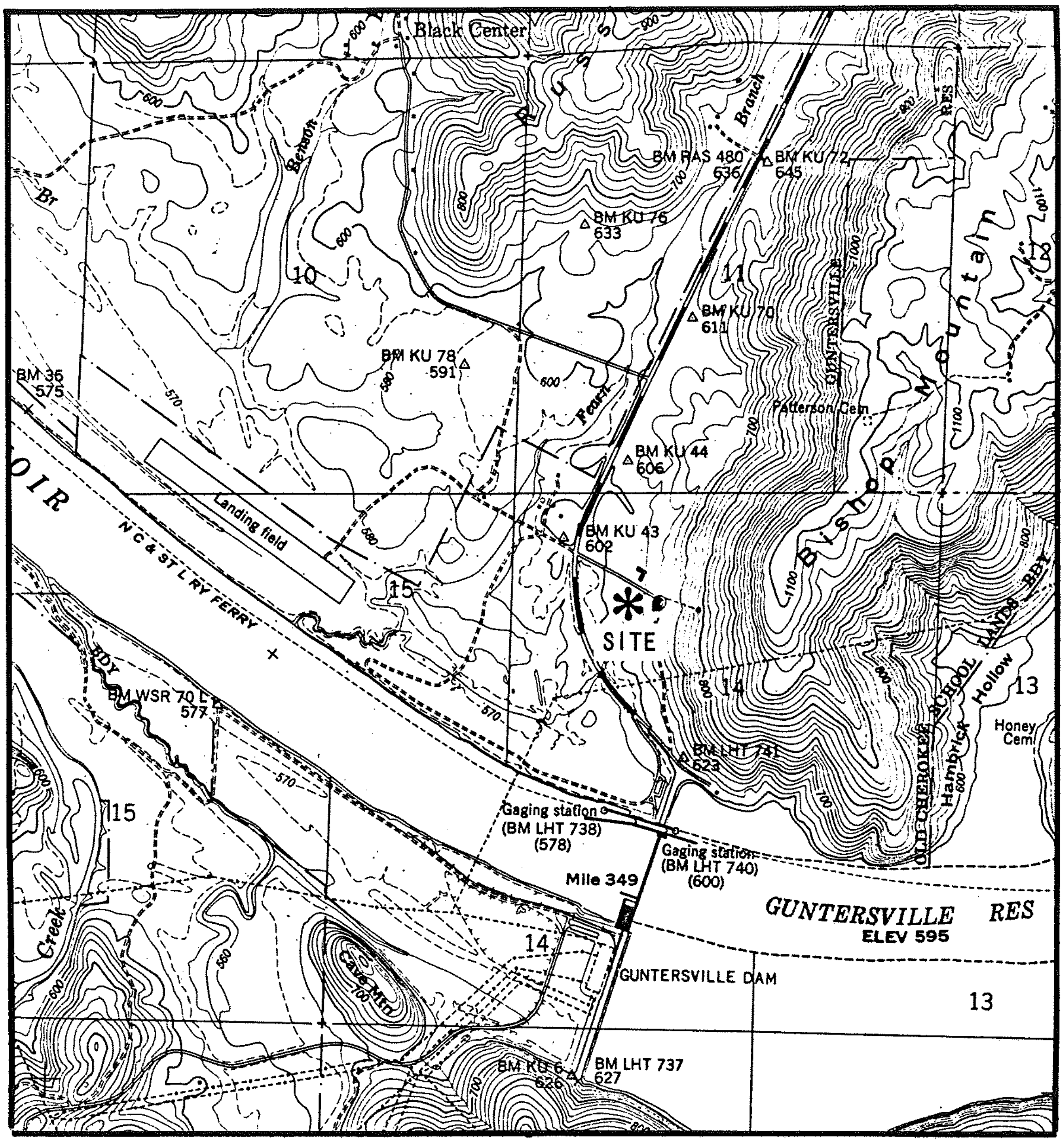


FIGURE 8. MAP LOCATION OF THE TVA SITE

TABLE V. MSFC (ALABAMA) GRAVITY NET

Base: Green Acres
Location: 0.8 mile northwest of the intersection between Martin and Anderson Roads on Redstone Arsenal, Huntsville, Alabama (Fig. 5)
Tie 1: Birmingham
Location: Lane Park about 0.5 mile north of the city zoo (Fig. 9)
Tie 2: Montgomery
Location 0.3 mile due west of the strip mine, north of the L&N switching yards, across the Alabama River at the bend of State Highway 143 at BM 150 on the topographic map (Fig. 10)

The North-South North American Gravity Net will be utilized in the LAG test program. The precise number of stations to be utilized has not been determined.

In order to establish the MSFC net, it was first necessary to obtain seismic background data. A preliminary survey consisting of seven runs (Fig. 11, SPACO not shown) was conducted with a three-axes seismometer (Fig. 12) loaned by the Plasma Physics Branch of Space Sciences Laboratory. The runs were selected on the basis that they almost represented the spectrum of seismic environments likely to be encountered. All runs were conducted as consistently as possible. The three-axis seismometer was first calibrated in all axes; however, only the Y (vertical) and Z (horizontal) axes were used. Information which could have been derived from the X axis was considered of minor importance to our machine as direct alignment with sources was not required.[1] A Mark 280, two-channel Brush Recorder was operated at a speed of 0.5 mm/sec on paper graduated to 10 millimicrons ($m\mu$) per division. A convenient expression of linear magnitude is $m\mu$. One $m\mu$ equals 10^{-9} meters. Run times varied from 30 minutes to 12 hours depending upon the information desired for each site environment. An electric power generator was placed

1. For this reason, the reader will note that the seismic disturbances have been identified with respect to the horizontal trace. The vertical trace consistently indicates less noise than the horizontal.

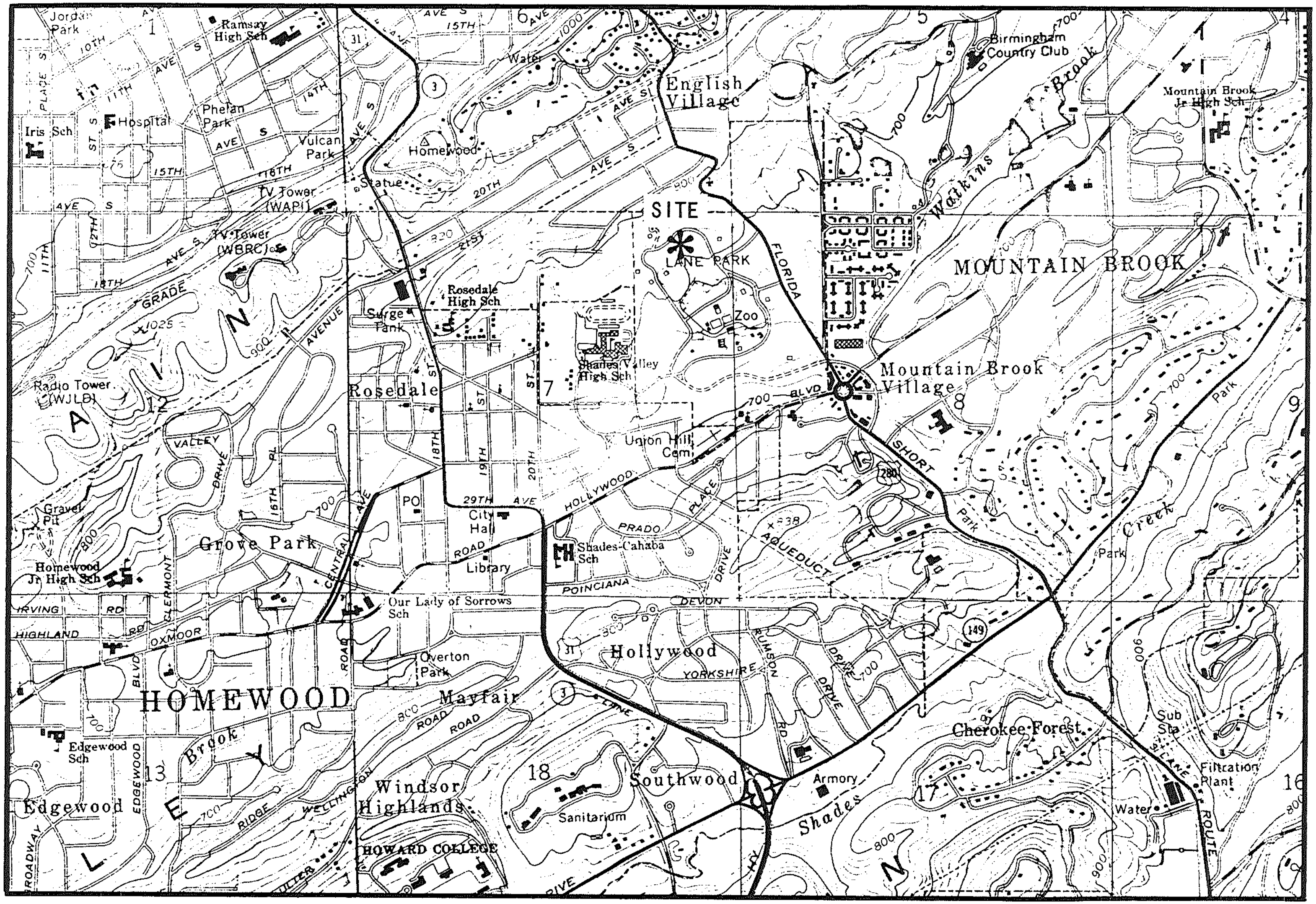


FIGURE 9. MAP LOCATION OF THE BIRMINGHAM SITE

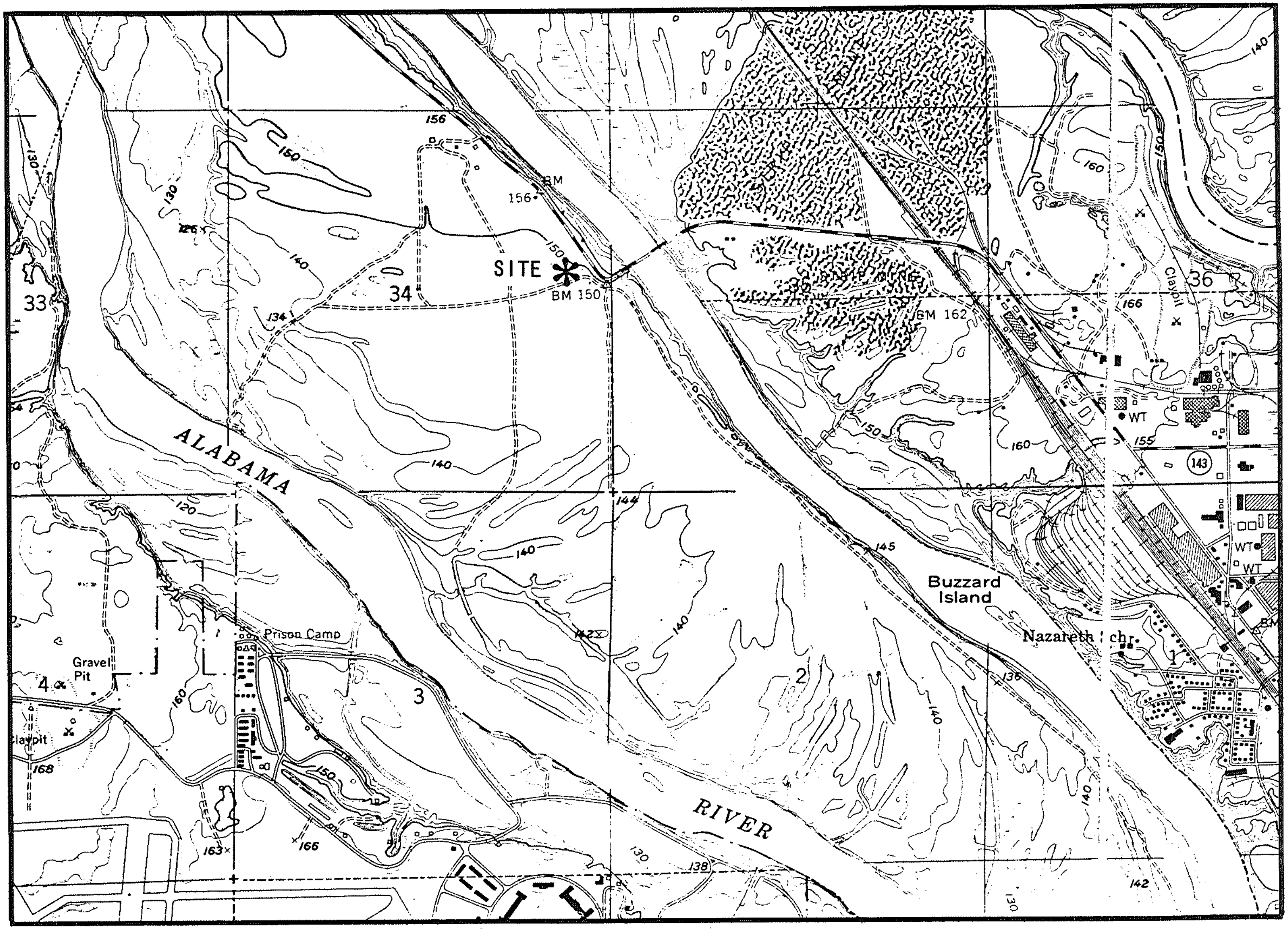


FIGURE 10. MAP LOCATION OF THE MONTGOMERY SITE

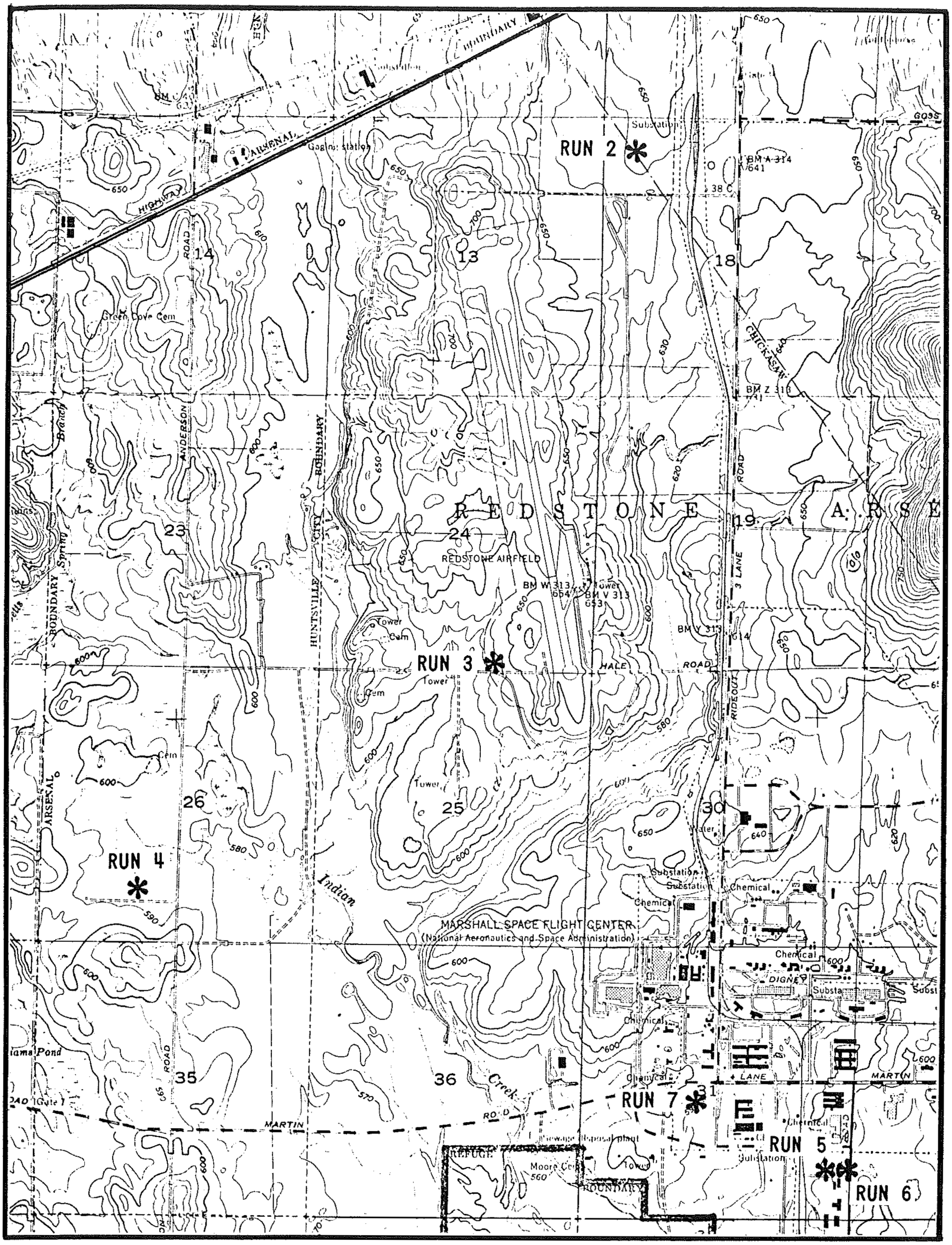


FIGURE 11. MAP LOCATION SHOWING THE SEVEN RUNS

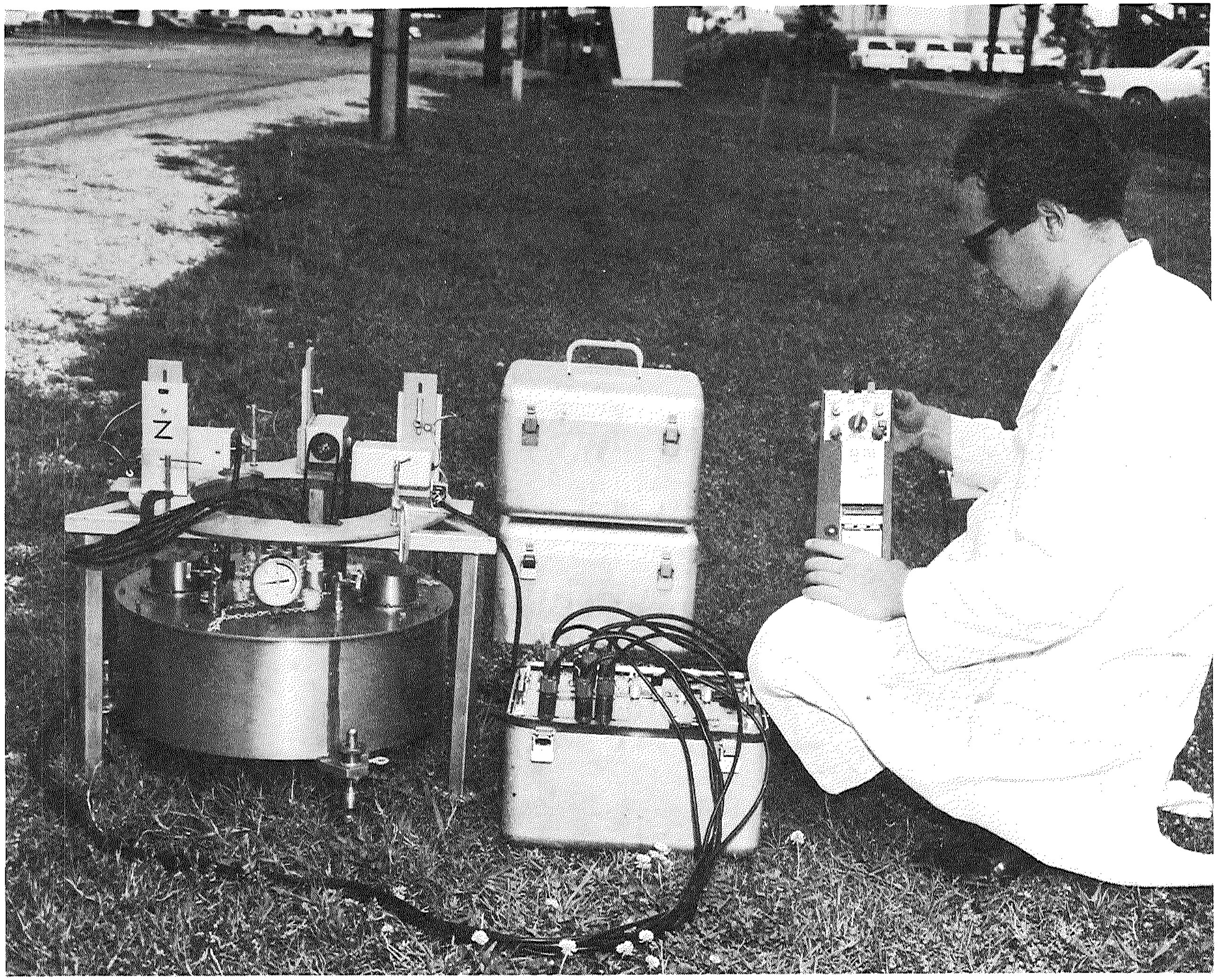


FIGURE 12. THREE-AXIS SEISMOMETER

about 150 feet away from the seismometer at the first outdoor field site, but because of the seismic-type noise, a very small generator was used at all other sites and placed about 500 feet away.

Run 1

Since the LAG was located at SPACO the first run was conducted there (Fig. 13) to determine the exact noise level with which the laboratory model LAG had been operating. This run was then used as the standard for all succeeding runs.

Run 2

The second run was made 0.5 mile southwest of Gate 9 on Redstone Arsenal (Fig. 14).

Run 3

The third run was made 0.4 mile due west of the south end of Redstone Airfield runway about 50 feet to the north of Hale Road (Fig. 15).

Run 4

The fourth run was made 0.5 mile north and about 0.4 mile west of the intersection of Martin and Anderson Roads (Fig. 16).

Run 5

The fifth run was made in the anechoic chamber at the Instrument Division of Test Laboratory on Redstone Arsenal (Fig. 17).

Run 6

The sixth run was made in the room immediately adjacent to and into which the anechoic chamber opens (Fig. 18).

FIGURE 13. FIRST SEISMIC TEST RUN — SPACO

FIGURE 14. SECOND SEISMIC TEST RUN SOUTHWEST OF GATE 9 — MSFC

FIGURE 15. THIRD SEISMIC TEST RUN WEST OF THE SOUTH END OF REDSTONE AIRFIELD

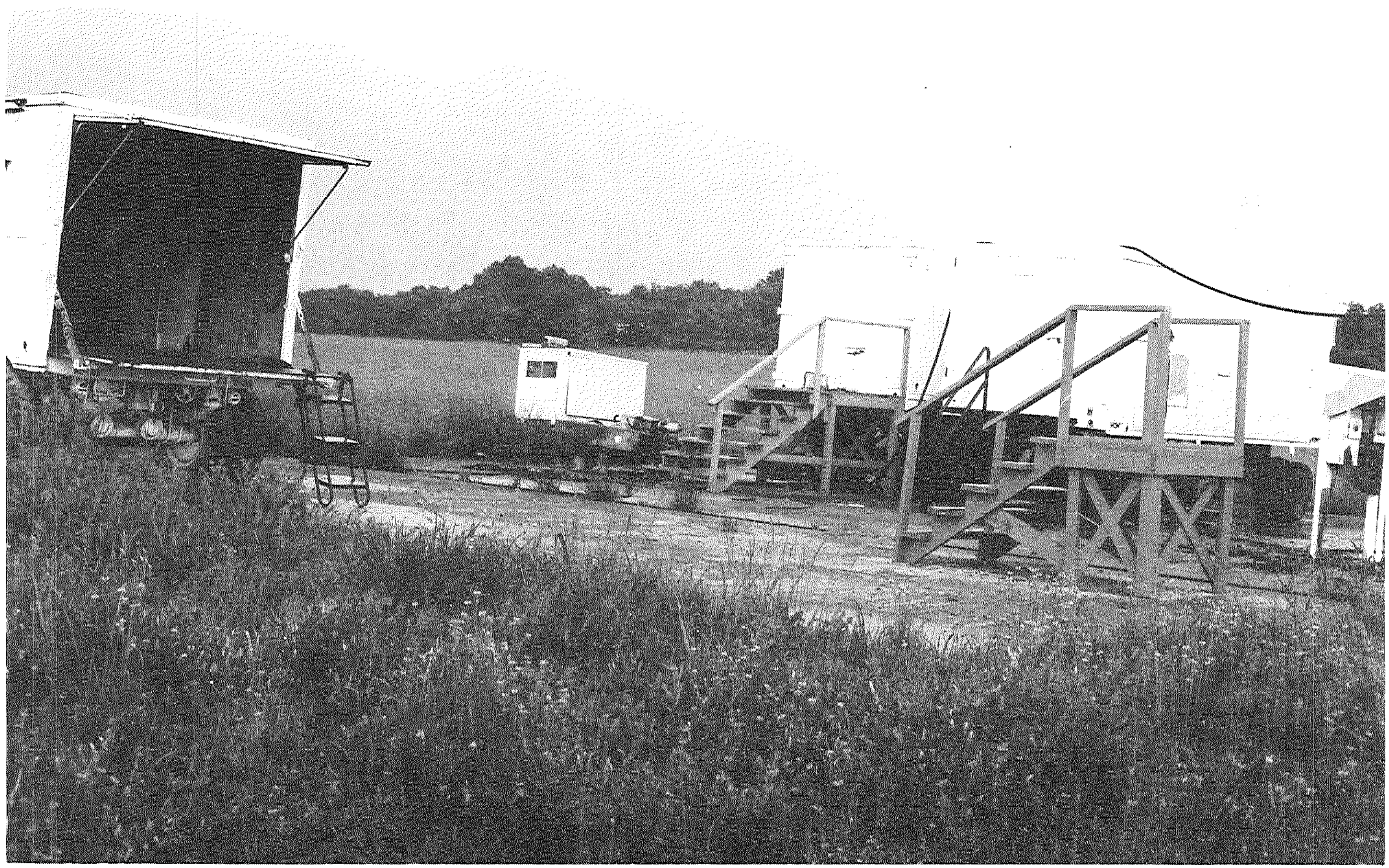


FIGURE 16. FOURTH SEISMIC TEST RUN NORTHWEST OF INTERSECTION OF MARTIN AND ANDERSON ROADS

FIGURE 17. FIFTH SEISMIC TEST RUN ANECHOIC CHAMBER TEST LABORATORY

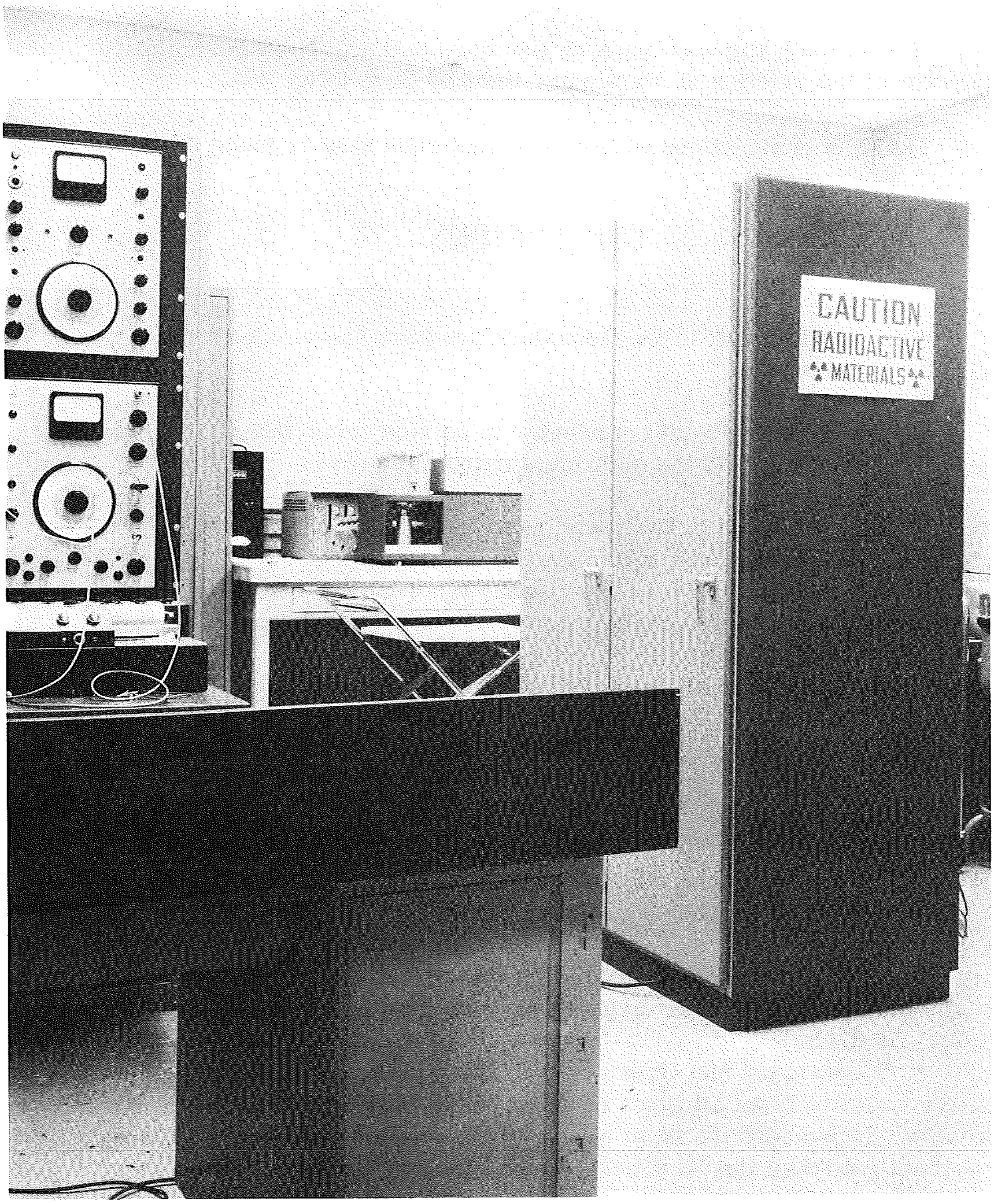


FIGURE 18. SIXTH SEISMIC TEST RUN ROOM ADJOINING ANECHOIC CHAMBER

Run 7

The seventh run was made on the Mars Softball Field immediately northwest of the junction of Martin and Rideout Road (Fig. 19).

Detailed descriptions of the individual runs may be found in the Appendix.

CONCLUSIONS

This initial effort in the field work program has yielded a number of positive conclusions.

Possibly the heaviest contributor to seisms, even though it is placed at least 500 feet away, is the portable electrical power generator.

Ground wind is a heavy contributor to noise in that its effects are passed into the ground from most sources covering large areas such as trees, foliage, and high grass. By placing a cover over the seismometer, the wind effect can be reduced by a factor of about 50 percent.

Ground traffic of all types affects the background as a function of distance, size, weight, and speed of the vehicle. Air traffic is a contributor at less frequency intervals than ground, and is an influencing factor as a function of distance and type.

Individual seisms (e.g., loud acoustical noises), tests involving the running of motors or shock affect the instrument. Aggregates of noise within the buildings from all sources provide intolerable backgrounds.

The vertical and horizontal traces are complementary with the vertical axis having greater magnitude for air traffic and loud low frequencies.

It is concluded that Green Acres is the optimum site because of its relative isolation from all types of seisms and the concrete pads and power available. It provided the least seismic background and was approximately 80 percent less than that at SPACO.[1]

---

1. Because of the indigenously optimum characteristics of Green Acres, this tract of land was acquired for Absolute Gravimeter utilization through the mutual cooperation of NASA and the U.S. Army.

FIGURE 19. SEVENTH SEISMIC TEST RUN AT THE MARS SOFTBALL FIELD

In this work, the effect of various noise sources on the seismometric equipment available has been demonstrated. An optimum site for gravimeter testing has been located and made available for use.[1]

1. Detailed investigation of the sites has, at the printing of this report, been completed and will be the subject of a second publication.

APPENDIX

Run 1

Date: 3-6-68

Experiment Initiation: 10:00 a. m.

Experiment Termination: 1:30 p. m.

Total Time: 3 1/2 hours

Wind: N/A

Weather: Sunny and clear

Temperature: 297° K

Average Seismic Background: 100 $m\mu$

Average Event Magnitude: 200 $m\mu$

Average Time Per Event: ~ 1 second

Purpose: To establish a set of environmental conditions, representative of seismic background, at the location of the working laboratory model of the LAG. These base data served as a comparator for all other seismic measurements run to determine precisely the conditions which can and cannot be tolerated by the gravimeter.

Results (Fig. 20): At this location, the seismic background is almost entirely an aggregate of indigenous building noise. Electric typewriters, the heating system, a large compressor (producing trace magnitudes of 300 to 350 $m\mu$), the telephone ringing (magnitudes of 250 to 300 $m\mu$), movement, walking (500 $m\mu$), and slamming doors (350 $m\mu$) were the major contributors sensed and recorded. Traffic on University Drive was also sensed and recorded. Individual vehicles produced magnitudes of 300 $m\mu$ and lasted from 5 to 8 seconds.

The forepump on the gravimeter itself was found to be a major source of noise. This was easily corrected by turning the forepump off after its performance requirements ceased.

A major periodic trace was caused by the starting and stopping of a large compressor located some distance away, but within the structure.

Wind, temperature, and climatic conditions were determined not to have appreciable effects on this indoor run.

Conclusions: It is evident that the gravimeter will operate under adverse backgrounds averaging in magnitude of 200 $m\mu$; however, greatly optimized readings of up to 150 $m\mu$ can be obtained by eliminating the forepump noise.

Run 2

Date: 3-16-68

Experiment Initiation: 4:30 p.m.

Experiment Termination: 10:00 p.m.

Total Time: 5 1/2 hours

Wind: Average 10 mph, gusts 25 mph

Weather: Sunny and clear

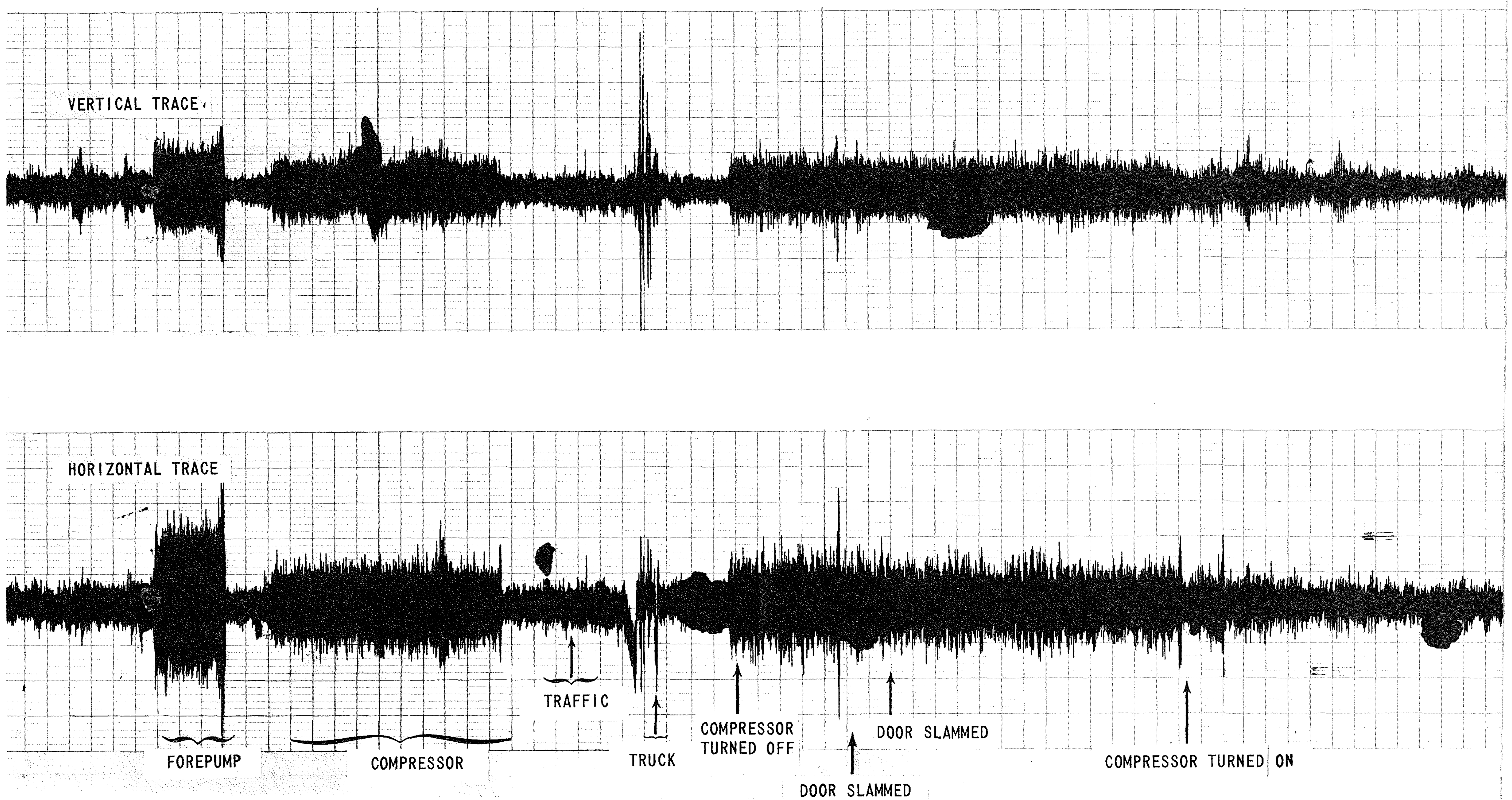
Temperature: 291°K

Average Seismic Background: 100 $m\mu$

Average Event Magnitude: 362 $m\mu$

Average Time Per Event: ~ 5 seconds

Purpose: To conduct an experiment on a site selected on the basis of its distance (in excess of 1 mile) from controlling structures, the most prominent of which are Ward and Weeden Mountains located on Redstone Arsenal. The area is relatively flat and is isolated from the majority of Arsenal noise, yet its relative proximity to Rideout Road (approximately 1/4 mile) and


VERTICAL TRACE
HORIZONTAL TRACE
FOREPUMP
COMPRESSOR
TRAFFIC
TRUCK
COMPRESSOR TURNED OFF
DOOR SLAMMED
DOOR SLAMMED
COMPRESSOR TURNED ON

2.

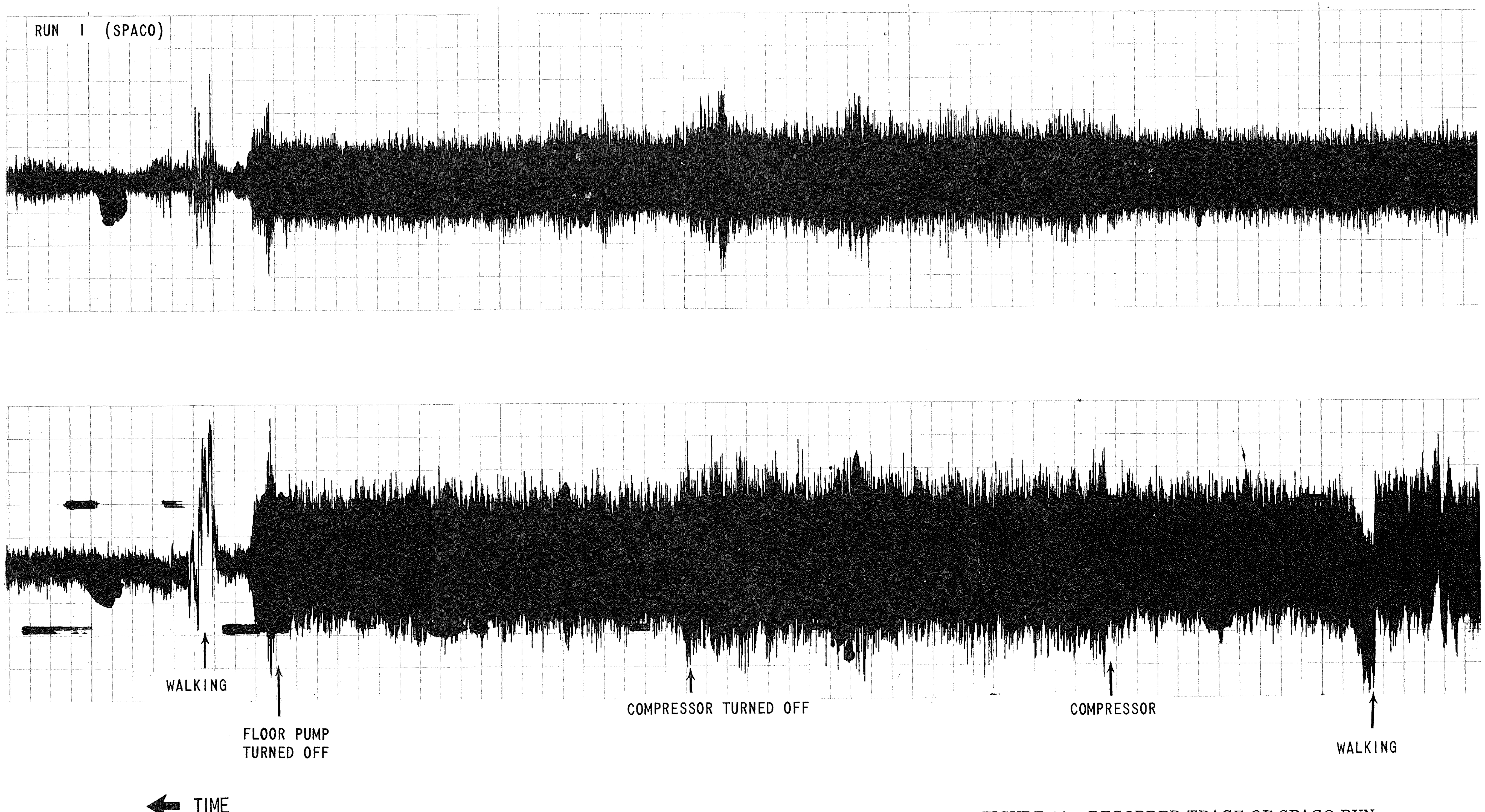


FIGURE 20. RECORDER TRACE OF SPACO RUN

Highway 72 (approximately 3/4 mile) provided data control on traffic flux. The site is located at the north approach to Redstone Airfield and relative measurements of air traffic effects were measured.

It was necessary to determine the aeolian effects on the seismometer, as well as translational effects through tall grass and trees surrounding the area.

Results (Fig. 21): A ground wind varying from 10 to 20 knots had distinct effects on the seismometer, resulting in magnitude traces of up to 300 to 350 $m\mu$, and producing aggregate magnitudes of 50 to 100 $m\mu$ by translations through the long grass and nearby clusters of trees and ground foliage.

The power for this first field test was derived from a large electrical power generator, placed about 150 feet away. In subsequent tests, a smaller power generator was used and placed 500 feet away, resulting in a noise reduction of about 62 percent. The seismometer was placed on the ground between two stacks of ammunition boxes. This shielding, plus additional board shielding, was unsatisfactory because it did not reduce the noise level.

Weather conditions were good, with no rain or clouds, and the temperature was comfortably within operating limits.

Conclusions:

(1) Air traffic produced distinctly measurable traces.

(2) In Arsenal traffic, only the heavier vehicles were recorded; however, there was no resultant aggregate background.

(3) The ground wind produced a continuous trace which contributed heavily to the total background. This noise results from wind striking the seismometer, grass, trees, and foliage.

(4) No other significant weather effects could be determined.

(5) A cover for the seismometer is necessary to shield it from the wind.

(6) It is necessary to place the generator as far away as the available cable will permit. Also, the size of the generator must be reduced, if possible, as the generator was a major contributor to noise.

Run 3

Date: 3-7-68

Experiment Initiation: 12:03 p. m.

Experiment Termination: 2:00 p. m.

Total Time: 1 hour 57 minutes

Wind: 7 mph

Weather: Sunny and clear

Temperature: 295°K

Average Seismic Background: 50 $m\mu$

Average Event Magnitude: 275 $m\mu$

Average Time Per Event: 5 seconds

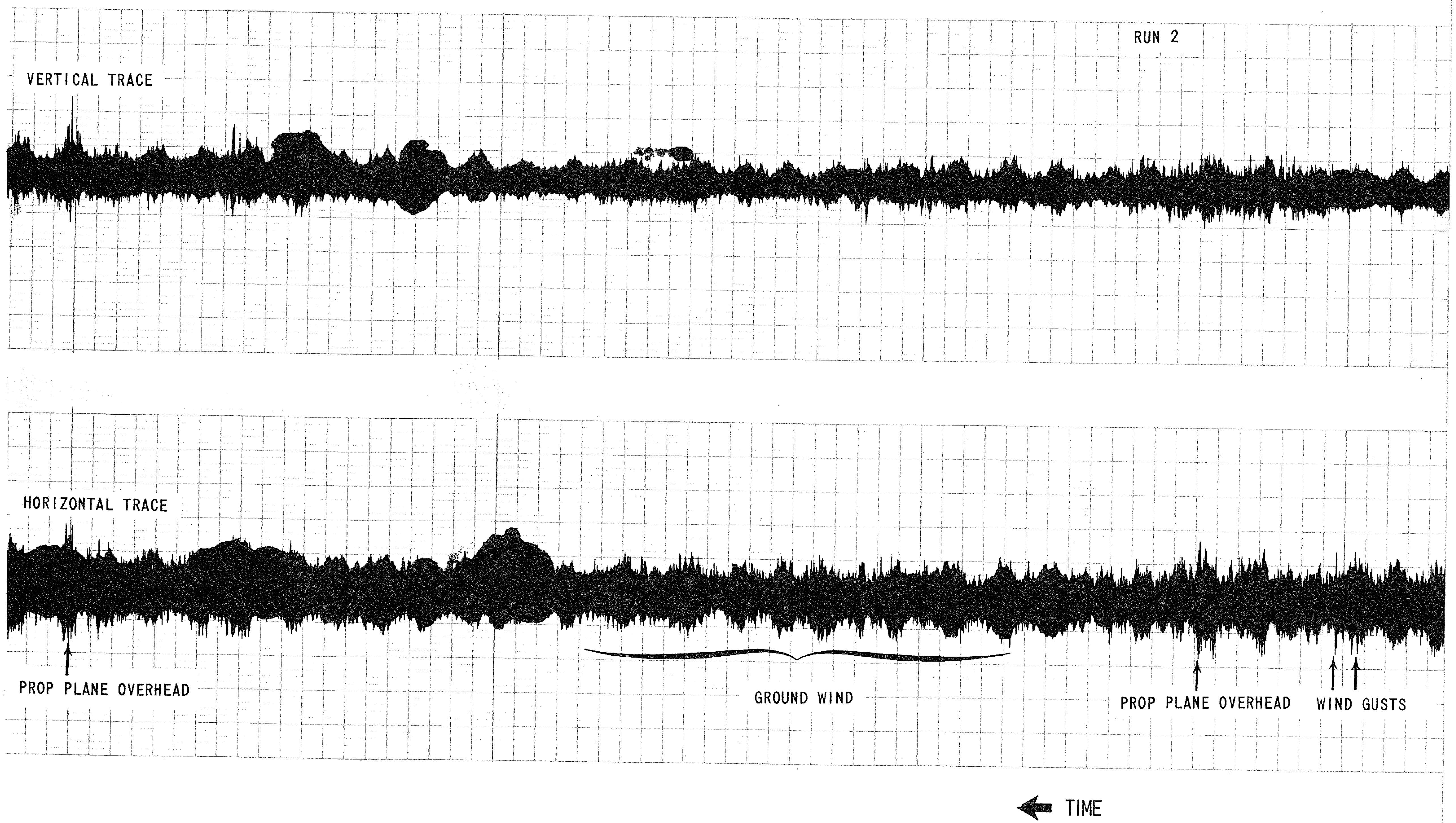
Purpose: To achieve the highest degree of isolation possible in an area free of most extraneous noises.

Results (Fig. 22): The selection of this area was based on two factors. The location is near the southern approach to Redstone Airfield and thereby provided good air traffic flux data on aircraft landing, taking off, idling, and passing overhead. It is well isolated from the majority of extraneous background noise and is also protected from the wind; therefore, a minimum of translation from grass is experienced.

For this run, a heavy aluminum tank about 1/2 inch thick, 3 1/2 feet in diameter, and 4 feet tall was placed over the seismometer to reduce wind effects.

A smaller portable generator (3-gallon fuel capacity) was used and placed 400 feet away. Over-all noise reduction resulted from the reduced size and isolation of the generator and covering of the seismometer.

There was apparently no translational noise effect from the short grass.


RUN 2
VERTICAL TRACE
HORIZONTAL TRACE
PROP PLANE OVERHEAD
GROUND WIND
PROP PLANE OVERHEAD
WIND GUSTS
TIME

(2)

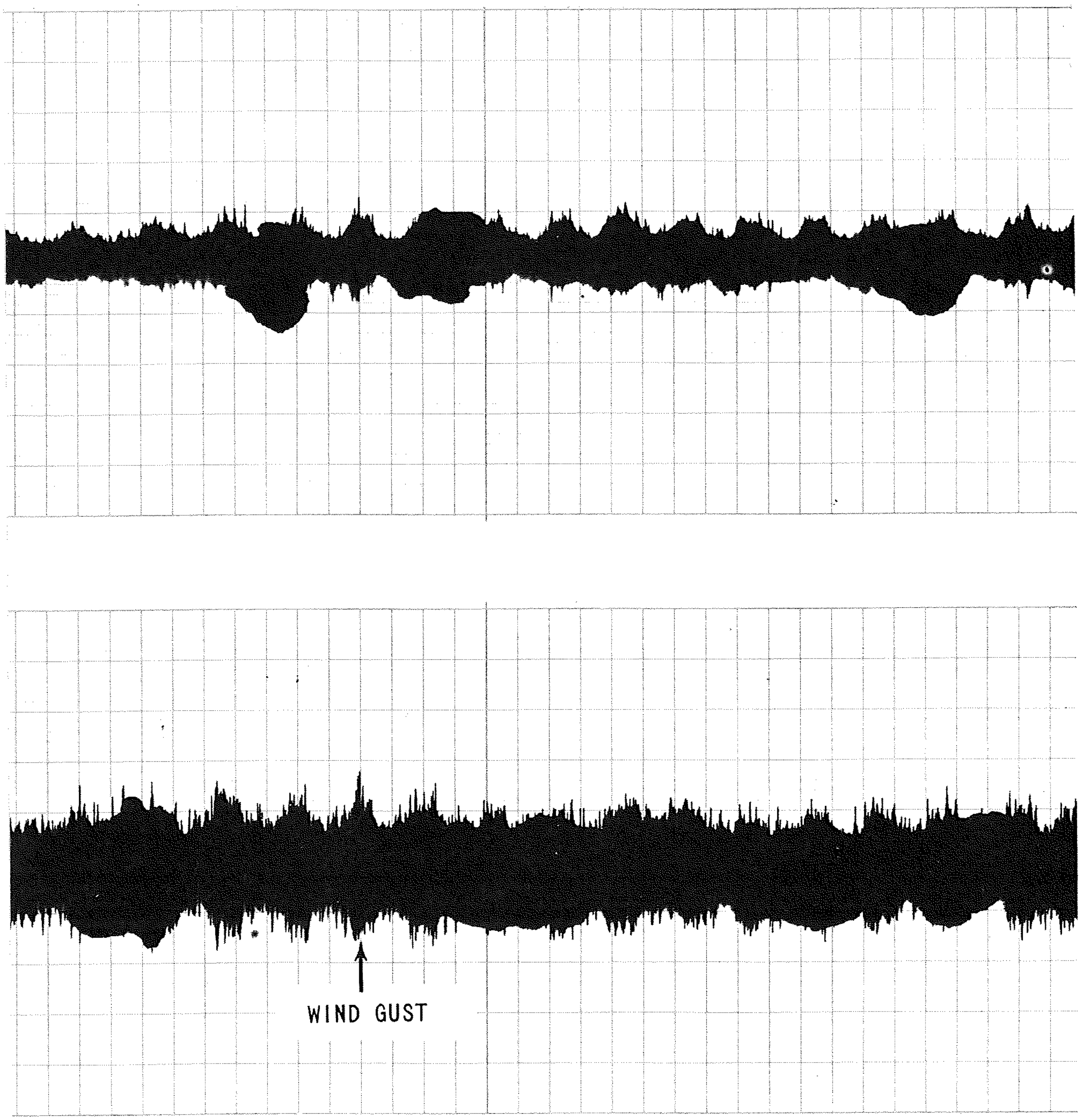


FIGURE 21. RECORDER TRACE OF RUN 2

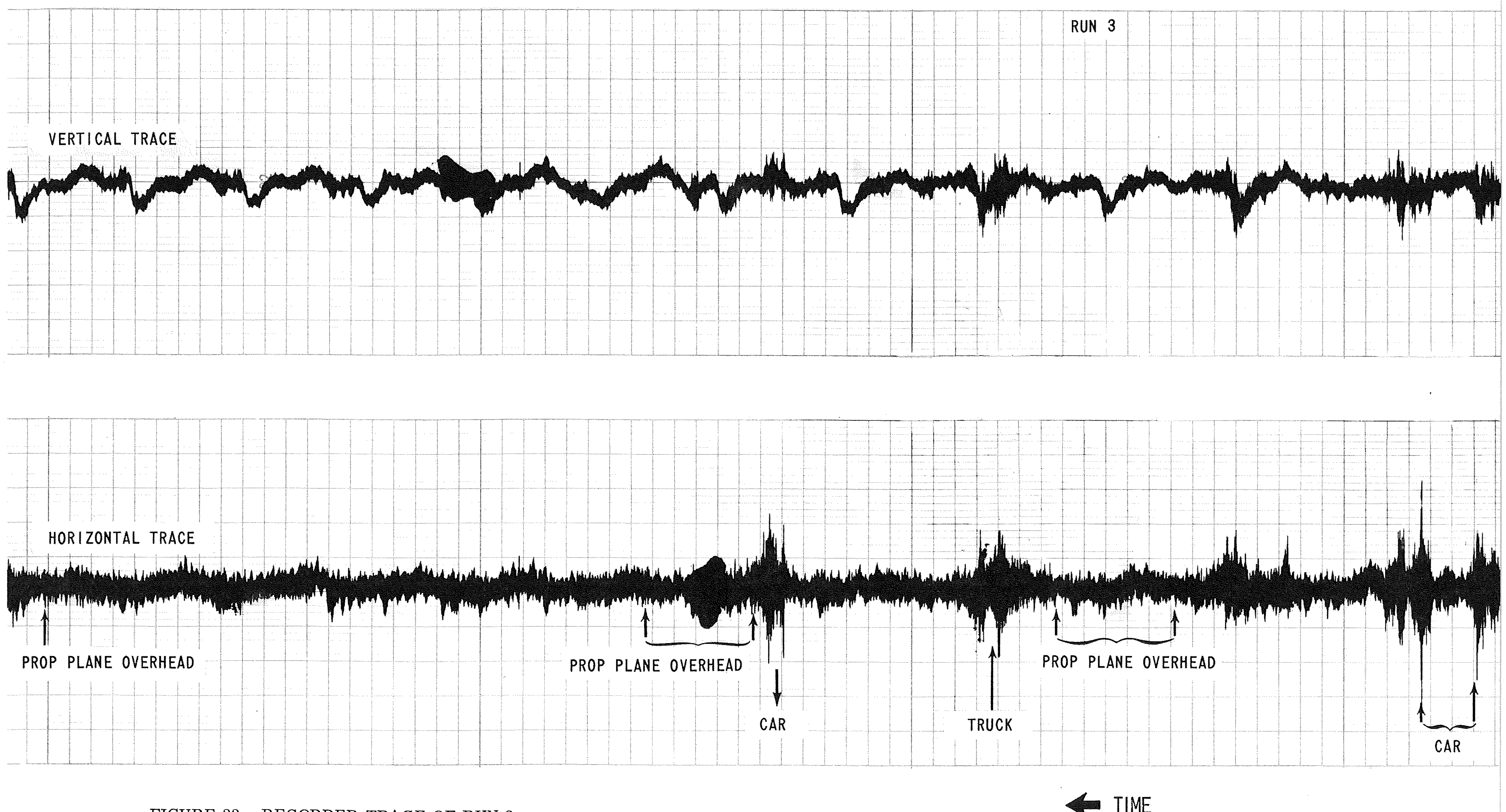
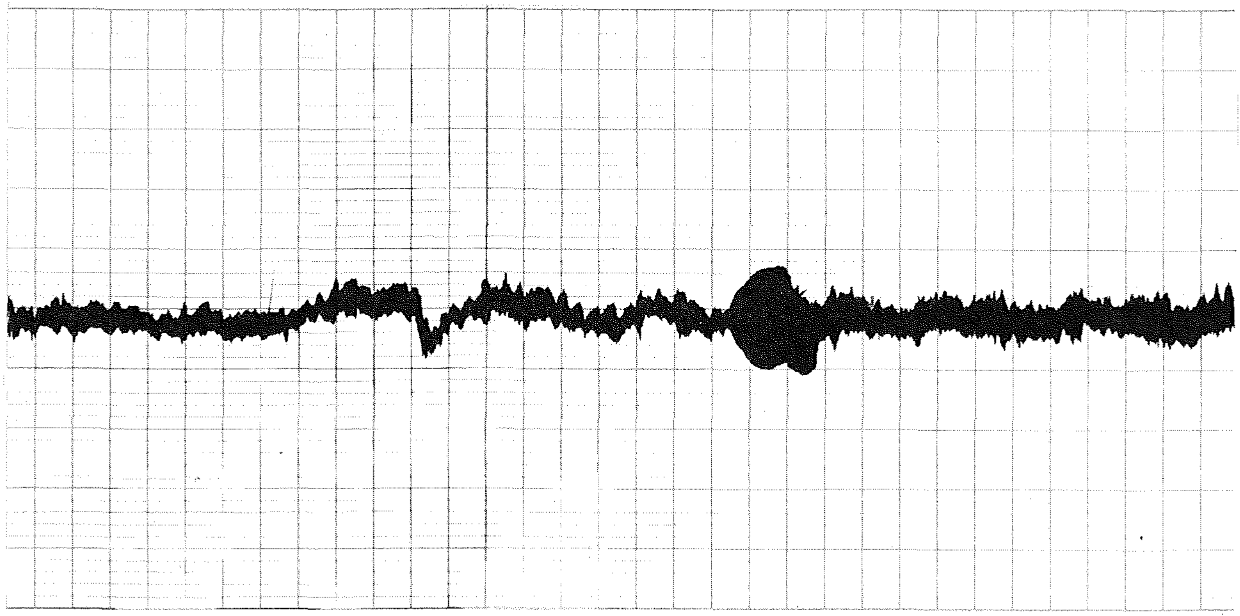
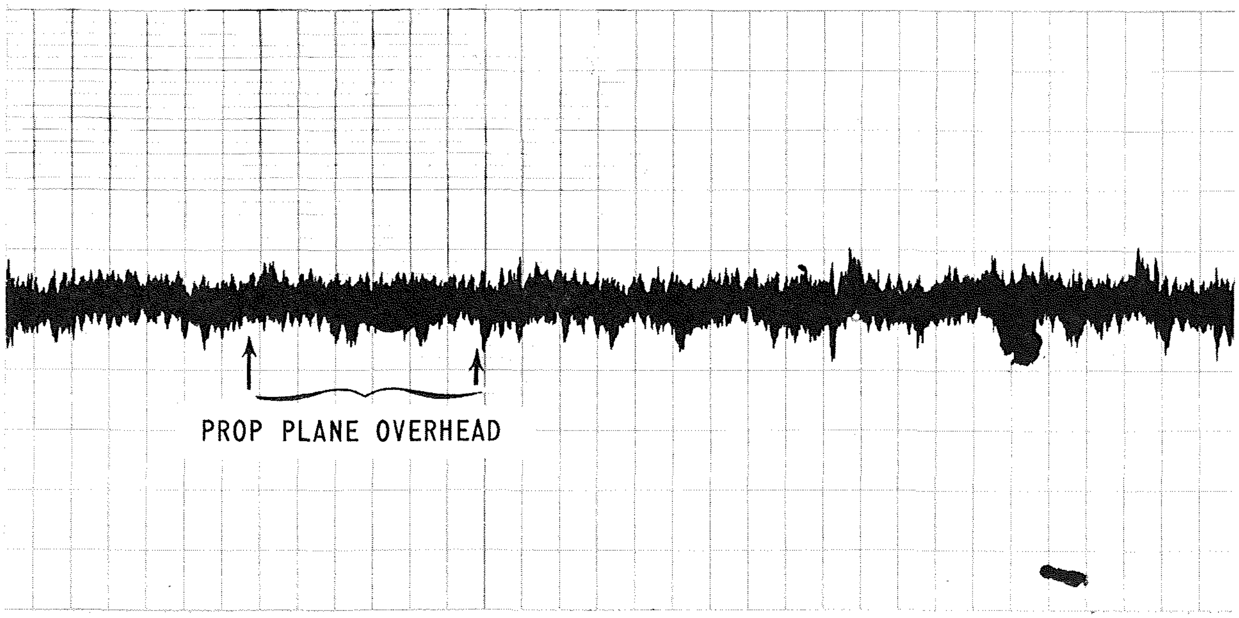


FIGURE 22. RECORDER TRACE OF RUN 3

2





Air traffic was consistent and averaged one plane landing, taking off, or passing overhead every 6 minutes.

Individual seisms resulted largely from single vehicles on nearby Hale Road. Dynamiting the large limestone quarry north of Huntsville constituted the only other unusual seisms.

All of the desired conditions were met within the elapsed time.

Conclusions:

(1) Air traffic produced very distinctive traces from aircraft landing, taking off, or idling. The vertical axis registered the greatest effect from aircraft passing overhead. The vertical and horizontal axes produced no significant differentiation between idling, taxying, landing, or taking off.

(2) Individual seisms from walking, the occasional passing of cars on a dirt road, the dynamiting, were recorded; however, they were of short duration, easily traceable and are of no great consequence to the general background.

(3) The weather had no appreciable effect that could be determined.

(4) The ground wind was negligible after the shielding had been emplaced. The overall effect was to improve the trace by a factor of about 50 to 60 percent.

(5) Wind translations from the short grass could not be determined.

(6) Isolation of the generator and reduction of its size in combination with the aluminum tank covering the seismometer resulted in a noise reduction of approximately 50 percent.

Run 4

Date: 3-7-68

Experiment Initiation: 3:50 p. m.

Experiment Termination: 5:30 p. m.

Total Time: 1 hour 40 minutes

Wind: About 7 mph

Temperature: 294°K

Average Seismic Background: 25 mμ

Average Event Magnitude: 200 mμ

Average Time Per Event: ~ 1 1/2 seconds

Purpose: To achieve maximum isolation from seismic influences in an outdoor environment.

Results (Fig. 23): Wind and wind effects through grass and trees, ground and air traffic, and noise from buildings and other outside influences were minimal.

Individual seisms were very infrequent and consist, for the most part, of air traffic.

The weather was sunny, clear, and mild.

Conclusions:

(1) Of all areas tested, this offers the best aggregate of desirable environmental conditions.

(a) It is isolated, therefore seisms of all types are very infrequent.

(b) The acreage is large, thereby lending itself to a variety of tests, if desired.

(c) Concrete pads are available on which to place equipment for field work.

(d) Power is available.

(e) The wind is relatively weak at almost all times.

(f) Wind effects from trees and foliage are small because they are at least 1/2 mile away.

(2) This site will be used for base gravimetric field operations.

(3) Although the generator was emplaced about 500 feet away, it is probable that it is the largest single contributor to background noise.

Run 5

Date: 3-7-68

Experiment Initiation: 7:30 p.m.

Experiment Termination: 7:30 a.m.

Total Time: 12 hours

Wind: N/A

Weather: Clear

Temperature: 296°K

Average Seismic Background: 300 mμ

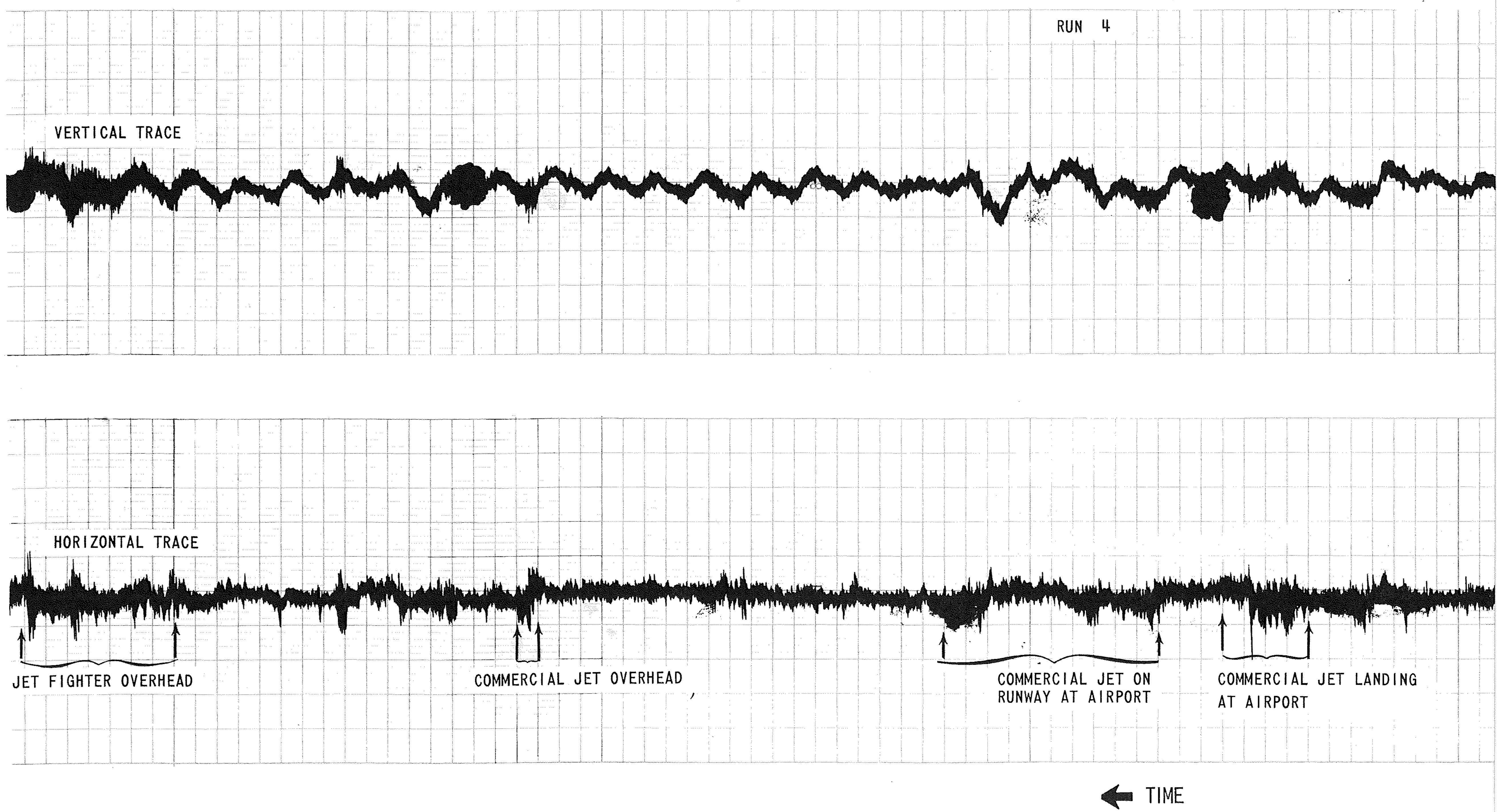
Average Event Magnitude: 325 mμ

Average Time Per Event: 2 1/2 seconds

Purpose: To achieve the highest degree of total isolation possible.

Results (Fig. 24): It was impossible to align the seismometer on the "chicken wire" mesh floor in the chamber. The instrument was placed on the doorsill, but the desired isolation was not achieved.

Inasmuch as the entire building (Building 4650) shakes from the test equipment mounted inside, the seismometer picked up the complete seismic aggregate which resulted in an average background magnitude higher by a factor approximately 25 percent than that at SPACO.


RUN 4
VERTICAL TRACE
HORIZONTAL TRACE
JET FIGHTER OVERHEAD
COMMERCIAL JET OVERHEAD
COMMERCIAL JET ON RUNWAY AT AIRPORT
COMMERCIAL JET LANDING AT AIRPORT
TIME

2

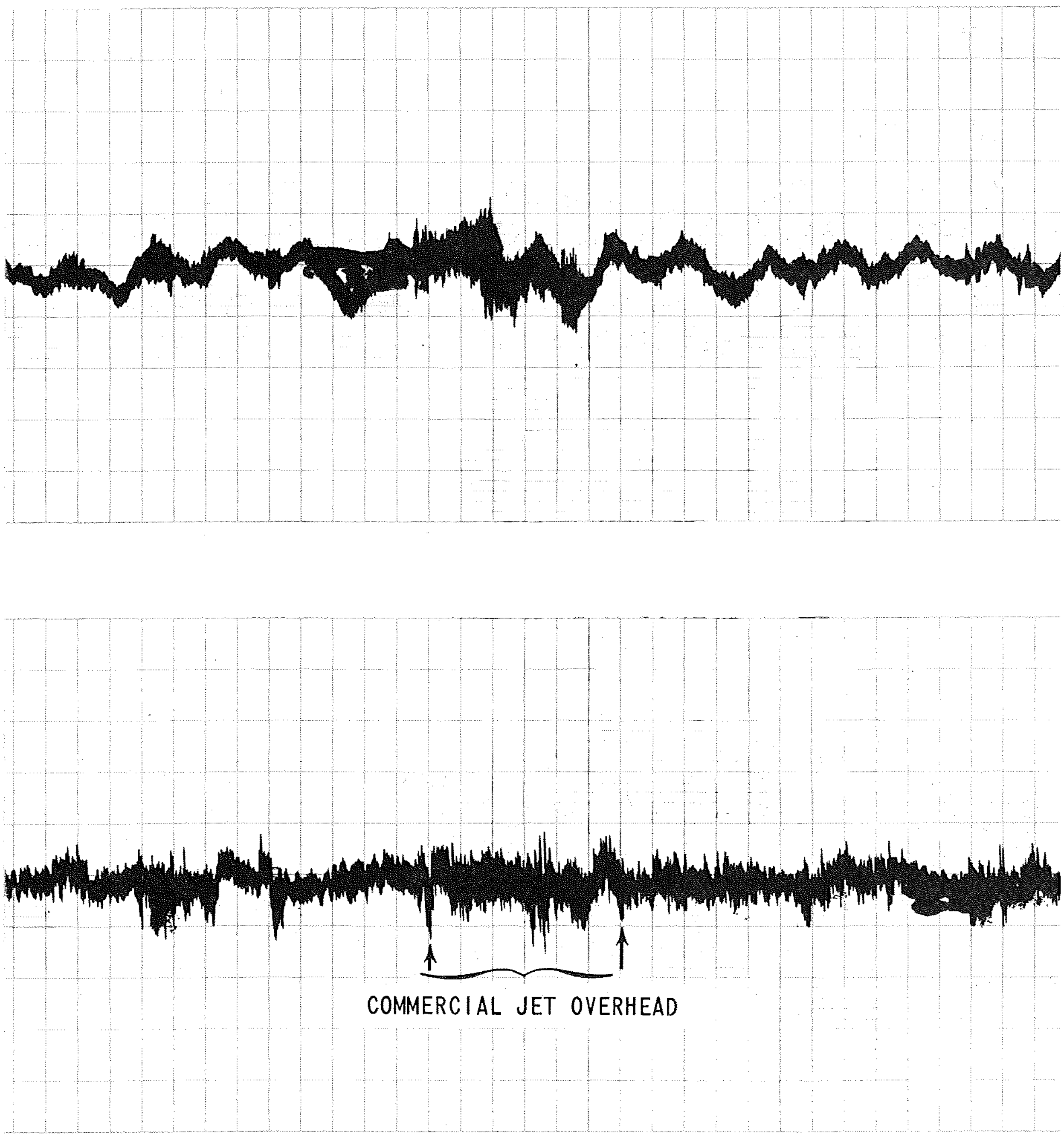


FIGURE 23. RECORDER TRACE OF RUN 4

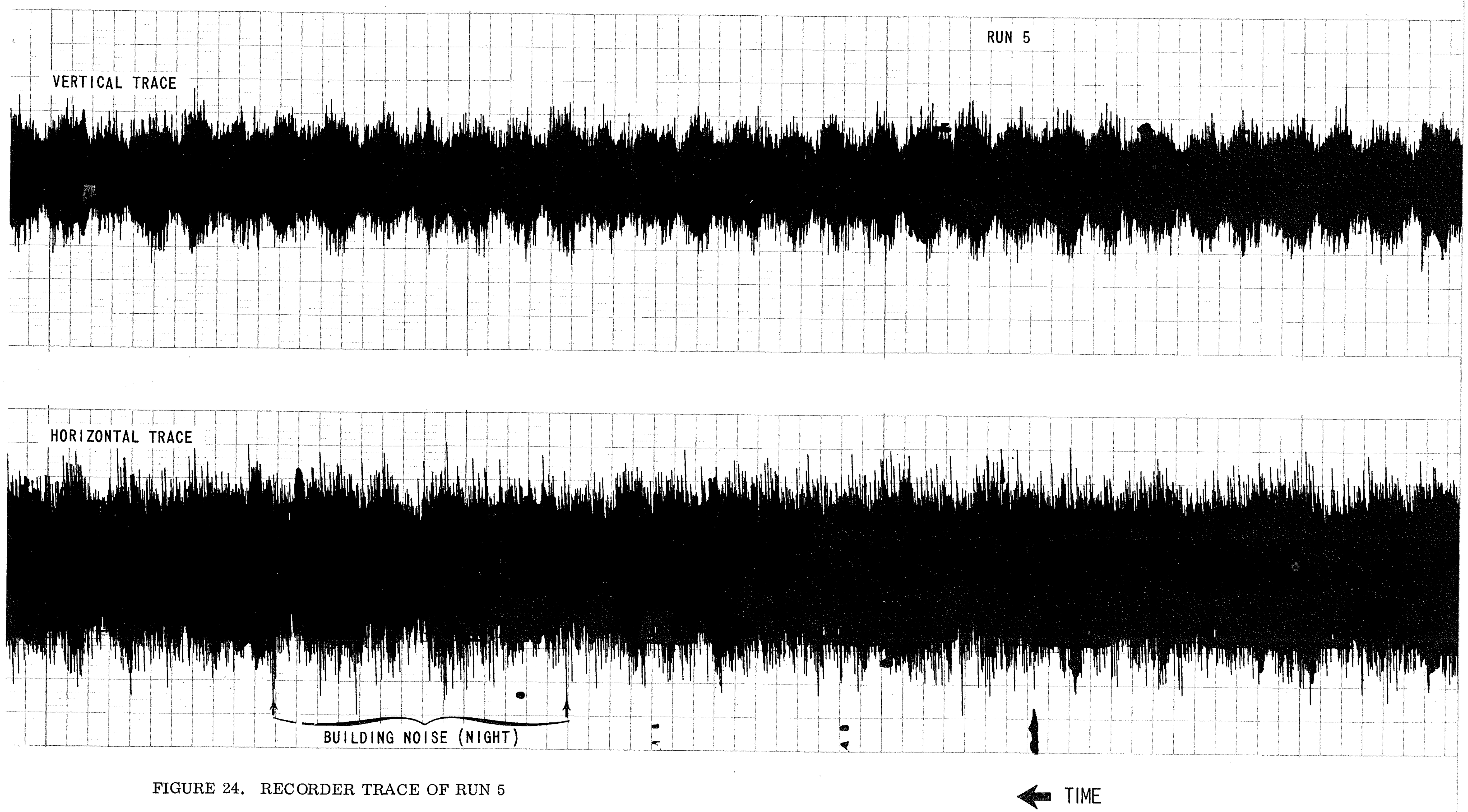
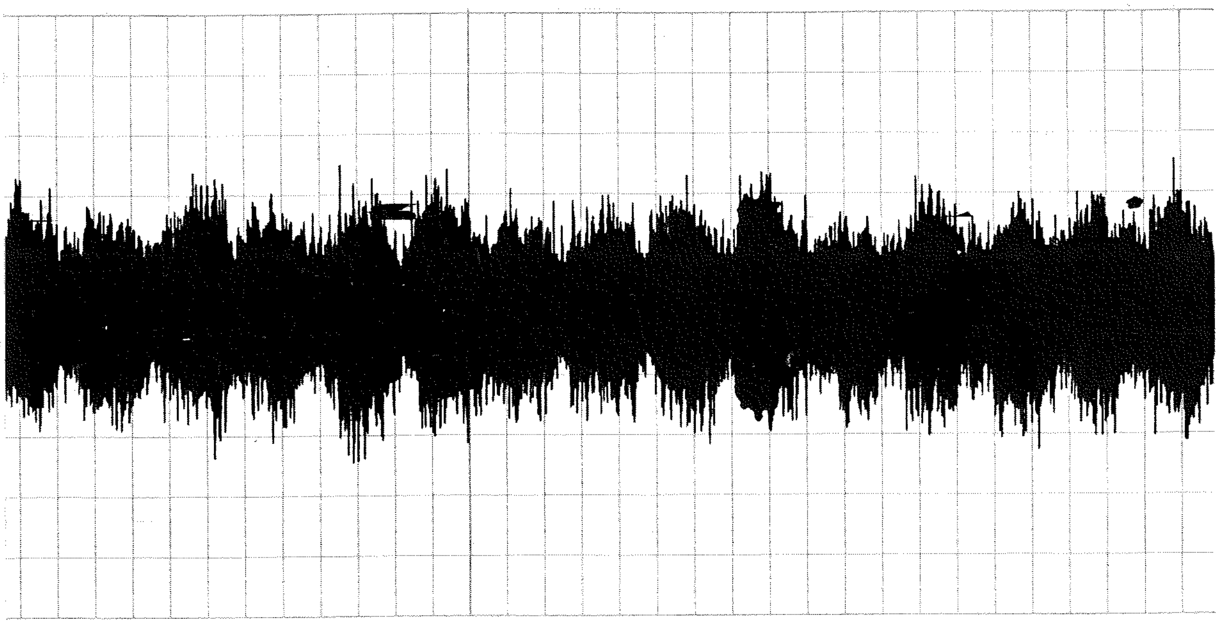
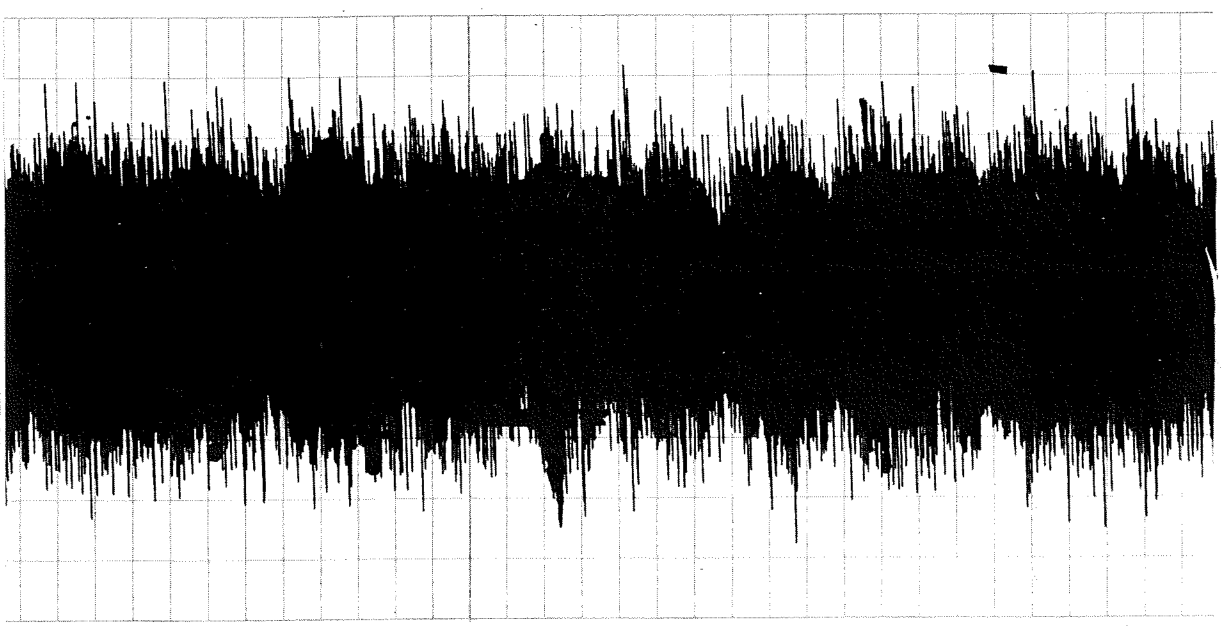


FIGURE 24. RECORDER TRACE OF RUN 5

2.





Conclusions:

(1) It is not practical to establish a gravity station in the anechoic chamber with the current equipment constraints.

(2) It was not determined that weather was an influencing factor in this test.

(3) There were no determinable wind effects.

(4) Noise from buildings of any type will present intolerable seismic masking.

Run 6

Date: 3-8-68

Experiment Initiation: 8:00 a.m.

Experiment Termination: 9:00 a.m.

Total Time: 1 hour

Wind: N/A

Weather: Sunny and clear

Temperature: 296°K

Average Seismic Background: 250 $m\mu$

Average Event Magnitude: 325 $m\mu$

Average Time Per Event: 2 1/2 seconds

Purpose: To determine whether or not there is any appreciable or characteristic difference between it and the anechoic chamber.

Results (Fig. 25): The resultant trace indicated a total background of approximately the same proportions as that recorded in the anechoic chamber. The seismometer picked up the complete seismic aggregate which produced a background approximately 25 percent higher than that recorded at SPACO.

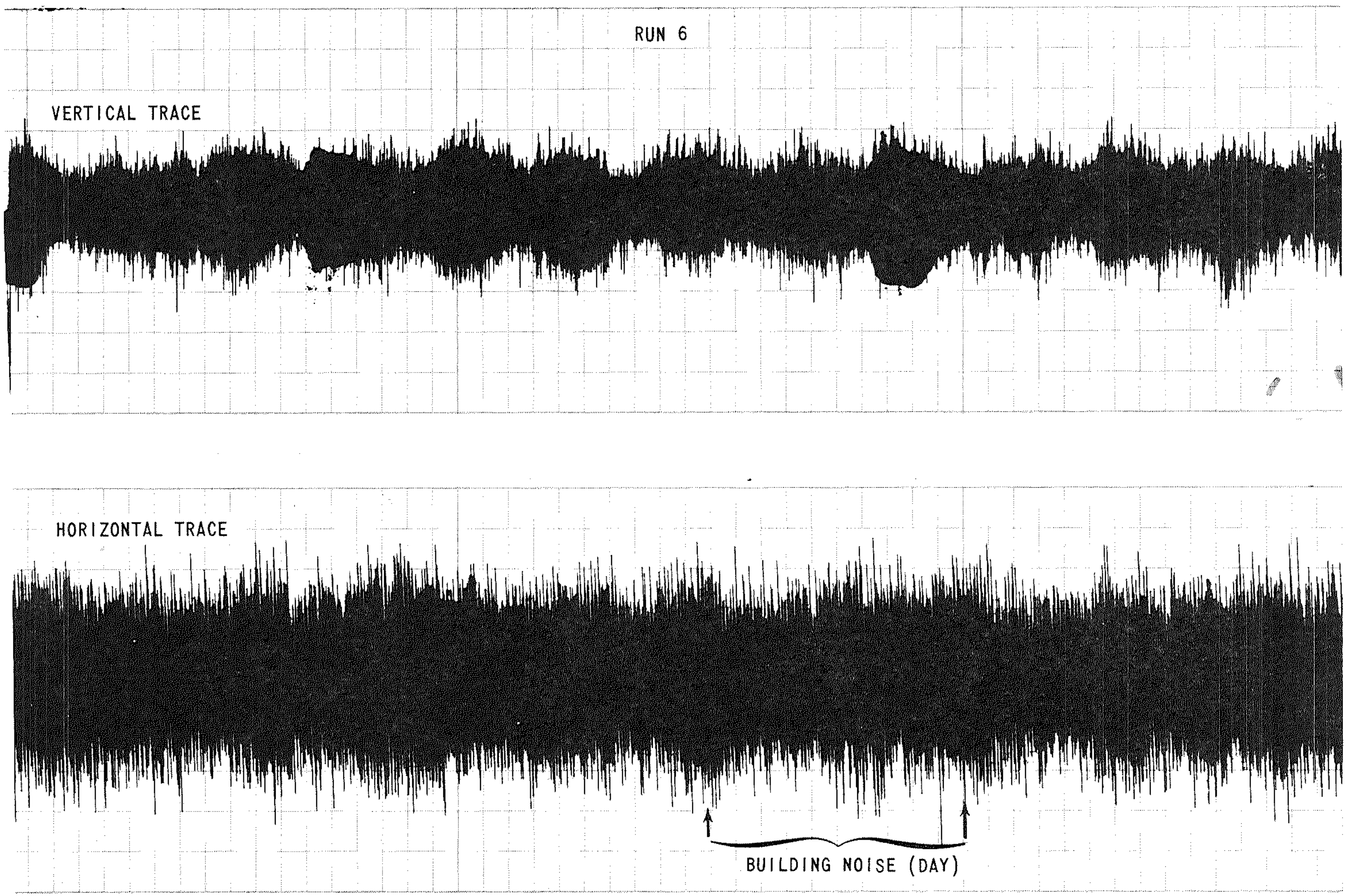


FIGURE 25. RECORDER TRACE OF RUN 6

Conclusions:

(1) Buildings are most unsuitable for housing the experiment or for establishing a gravity station due to seismic masking which produces gross errors in "g" readout on the gravimeter.

(2) Weather could not be determined as an influencing factor in this test.

(3) There were no apparent wind effects.

Run 7

Date: 3-8-68

Experiment Initiation: 9:55 a.m.

Experiment Termination: 10:26 a.m.

Total Time: 31 minutes

Wind: About 5 mph

Weather: Sunny and clear

Temperature: 293°K

Average Seismic Background: 1100 $m\mu$

Average Event Magnitude: 310 $m\mu$

Average Time Per Event: ~ 3 - 5 seconds

Purpose: To measure a cross section of noise at Redstone Arsenal and at the same time achieve isolation from the effects of noise within nearby buildings. The area is surrounded by roads less than 1/4 mile distant.

Results (Fig. 26): Individual incidents occurred at the rate of about 2 per minute.

Air traffic was also constant at the rate of approximately 1 every 3 minutes.

Steam exhausts proved to be a constant noise factor, occurring at the rate of approximately 1 blast every 2 minutes.

Conclusions:

(1) Air and ground traffic contributed heavily to background.

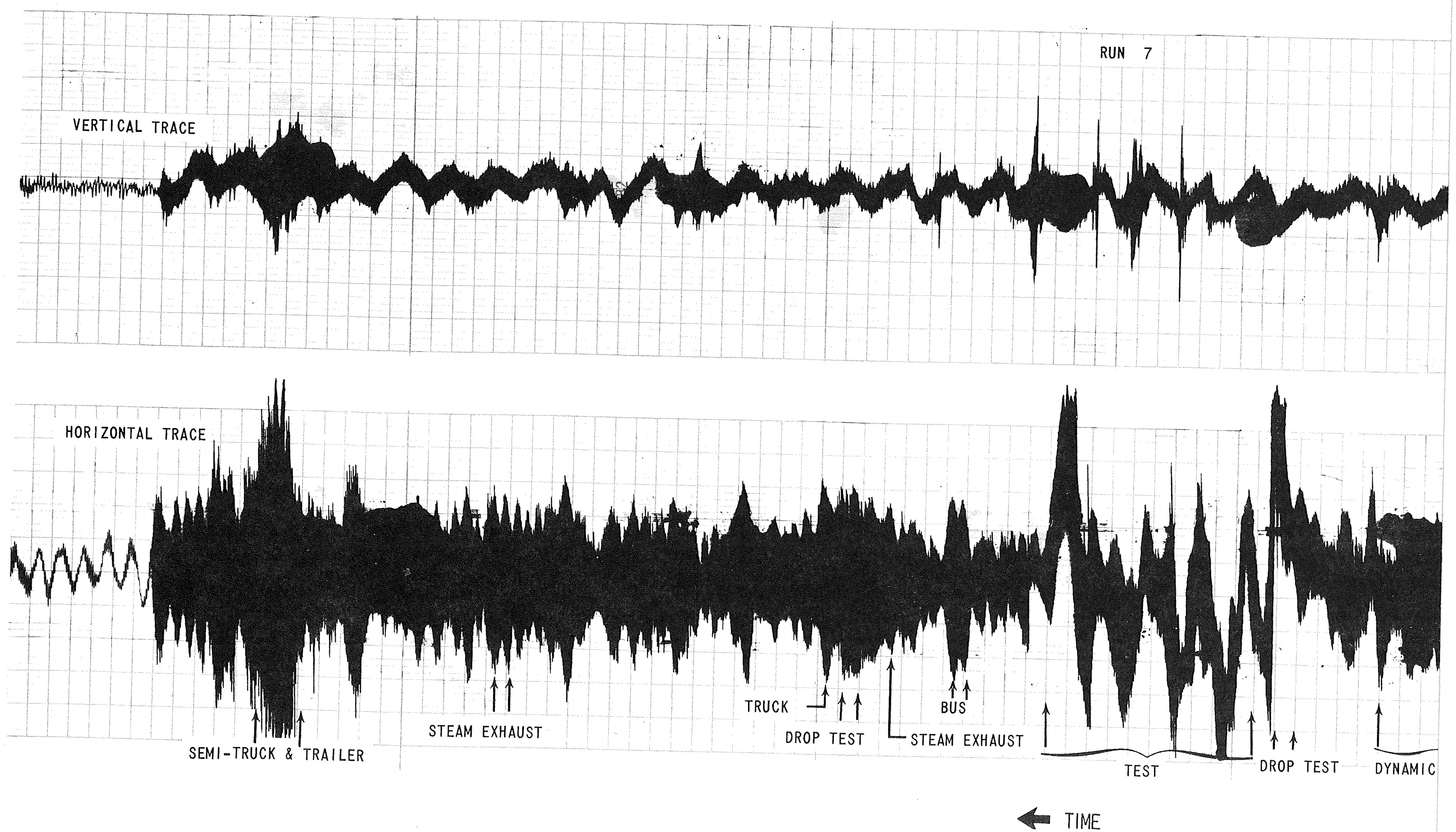
(2) The location is subject to intermittent seisms dependent on Arsenal activity.

(3) Air and ground traffic, construction equipment, test equipment, steam exhausts, and aggregate seisms from normal routine at the Arsenal has an average duration of 7.5 seconds.

(4) Low frequency noises strongly affect the seismometer.

(5) Ground wind has little effect if a tank is placed over the experiment. The grass is short and there are no trees close by; therefore, translated noise from foliage was a small factor.

(6) However, it is concluded that most of the above described noise can be eliminated in an isolated location.


RUN 7
VERTICAL TRACE
HORIZONTAL TRACE
SEMI-TRUCK & TRAILER
STEAM EXHAUST
TRUCK
DROP TEST
STEAM EXHAUST
BUS
TEST
DROP TEST
DYNAMIC
TIME

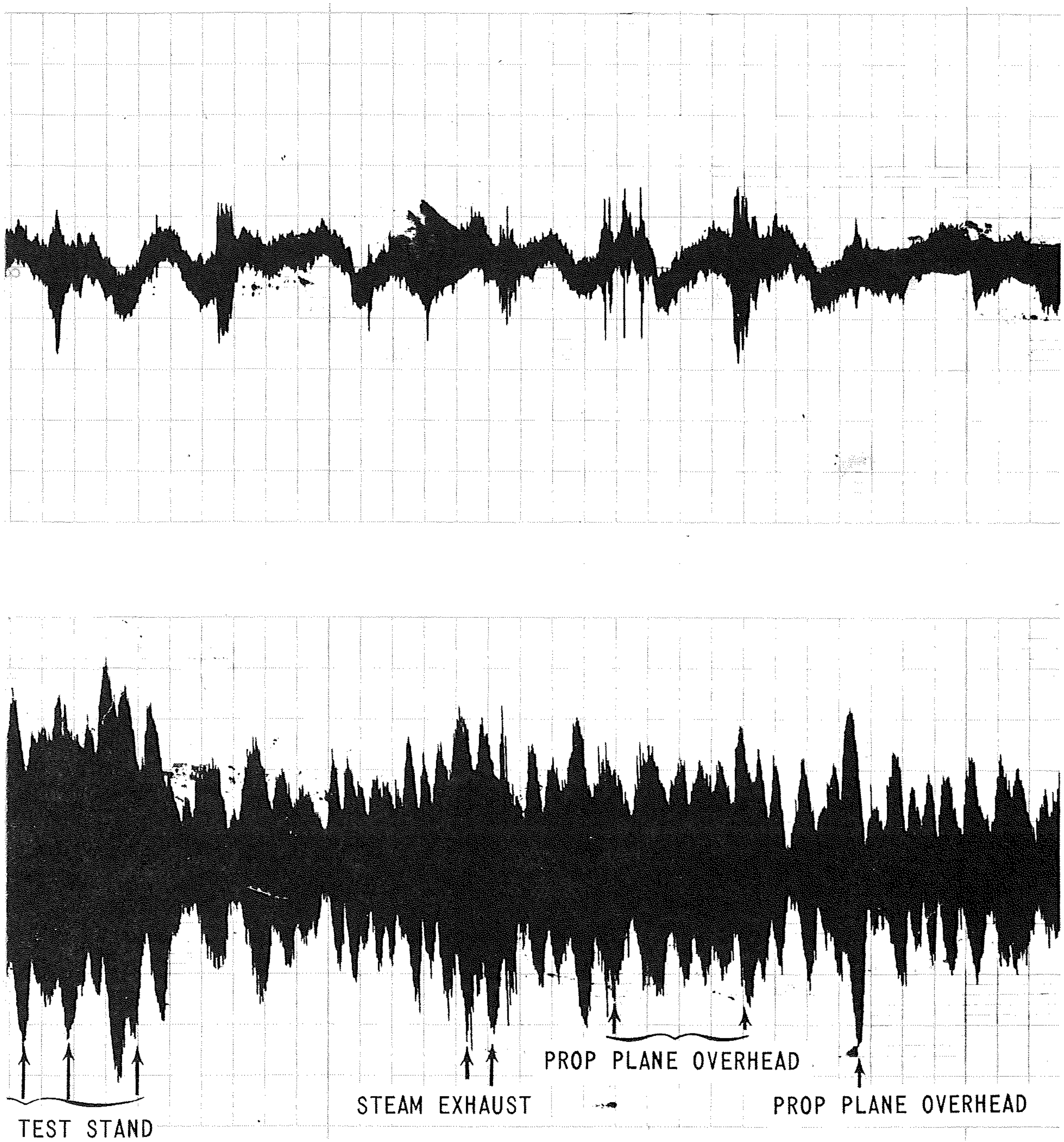


FIGURE 26. RECORDER TRACE OF RUN 7

APPROVAL

MARSHALL SPACE FLIGHT CENTER GRAVITY NETWORK

By William M. Greene

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

WERNER SIEBER
Chief, Scientific Engineering Division

GERHARD B. HELLER
Director, Space Sciences Laboratory

DISTRIBUTION

INTERNAL

DIR

DEP-T

AD-S
Dr. Ernst Stuhlinger

A&TS-PAT
Mr. L. D. Wofford, Jr.

PM-PR-M

A&TS-MS-H

A&TS-MS-IP (2)

A&TS-MS-IL (8)

A&TS-TU (6)

Author (50)

PD-AP-DIR
Mr. Hal Becker

PD-MP-Dir
Mr. James Downey
Mr. Herman Gierow

PD-AP-L
Mr. James A. Belew
Mr. William R. Perry

S&E-SSL-DIR
Mr. Gerhard B. Heller

S&E-SSL-C
Reserve (10)

INTERNAL (Continued)

S&E-SSL-S
Dr. Werner H. Sieber
Dr. O. K. Hudson
Mr. John Bensko

S&E-SSL-NP
Dr. Ilmars Dalins

S&E-AERO-YR
Mr. Otha H. Vaughn, Jr.

EXTERNAL

Scientific and Technical Information
Facility (25)
P. O. Box 33
College Park, Maryland 20740
Attn: NASA Representative (S-AK/RKT)

United States Geological Survey
Surface & Planetary Exploration
601 E. Cedar
Flagstaff, Arizona 86001
Attn: Dr. Al Chidister
Dr. Dave Dahlem
Dr. Gordon Swann
Dr. George Ulrich

United States Geological Survey
345 Middlefield Road
Menlo Park, California 94025
Attn: Dr. Henry Moore

DISTRIBUTION (CONCLUDED)

EXTERNAL (Concluded)

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103
Attn: Dr. Roy Brereton
Mr. Ritchie Coryell

SPACO, Inc.
3022 University Drive, NW
Huntsville, Alabama 35805
Attn: Mr. John Hatch
Mr. Clarence Ellis

Electroradiation Section
U. S. Army Metrology Center
Redstone Arsenal, Alabama 35812
Attn: Mr. Donald B. Cook

Atlantic Richfield Company
North American Products Division
Research and Development Department
P. O. Box 2819
Plano, Texas 75221
Attn: Dr. H. F. Dunlap

NASA Headquarters
L'enfant Plaza, North
Washington, D. C.
Attn: Dr. Donald U. Wise
Dr. Richard J. Allenby, Jr.
Mr. Jerald M. Goldberg
Mr. Robert P. Bryson
Mr. Floyd Roberson

U. S. Army Topographic Command
Corps of Engineers
6500 Brooks Lane
Washington, D. C. 20315
Attn: Mr. Ostreim, 14700